

4. Required Modeling Assumptions and Algorithms

Most of the modeling assumptions and algorithms about building operation and climate are either fixed or restricted when an ACM is used for compliance.

All approved ACMs ~~must~~shall include and automatically use all the appropriate fixed and restricted inputs and calculation methods with no special entry required by the user. Users may not override the fixed inputs when the ACM is used for compliance calculations, nor ~~may they be~~are users allowed to go beyond the limitations of the restricted assumptions.

The fixed and restricted modeling assumptions apply to both the *Standard Design* run and to the *Proposed Design* run. The *standard* fixed and restricted modeling assumptions always apply to the *Standard Design* run and are the *default* for the *Proposed Design* run. In some cases, the CEC has approved *alternate* fixed and restricted modeling assumptions that may be used in the *Proposed Design* run. When the assumptions differ between the *Standard Design* and the *Proposed Design*, this is called to the attention of the reader in this chapter. The alternate modeling assumptions may only be used when the *Proposed Design* run has a special building feature (e.g. zonal control) that is recognized as an approved ~~Exceptional Method~~ for credit, and the ACM has been approved with this ~~optional~~ modeling capability. The modeling of such building features for compliance purposes ~~must~~shall always be documented as ~~entries in the *Special Features and Modeling Assumptions* listings on the Certificate of Compliance and on the Computer Method Summary.~~

~~The following subsections describe the fixed and restricted modeling assumptions or computer inputs and explain how they apply to both the *Standard Design* run and the *Proposed Design* run.~~

~~When~~While this manual describes the algorithms and calculation methods used by the reference method, an ACM may use alternative algorithms to calculate the energy use of low-rise residential buildings provided that the algorithms are used consistently for the *Standard Design* and the *Proposed Design* and provided that the ACM passes the applicable tests described in Chapters 5 and 6 ~~and provided that the appropriate input summaries and output information is correctly produced by the ACM. The reference methods of calculation are implemented in the CALRES computer program and used to generate the tests in Chapters 5 and 6.~~

~~However, certain algorithms and calculational procedures such as water heating and duct efficiency calculations must be modeled to produce intermediate results precisely and in detail. Typically the tests for these procedures will consist of random testing and result comparison of these intermediate results from a large number of possible tests and conditions.~~

4.1 General Modeling Assumptions

4.1.1 ~~4.10~~ Standard Weather Data

~~**Standard Design & Proposed Design:**~~ All ACMs ~~must~~shall use standard hourly weather data for all compliance runs. ~~The standard weather data may be condensed, statistically summarized, or otherwise reduced. However, the basis must be the official Commission's hourly weather data. The same hourly weather data and weather data format must~~shall be used for both the *Standard Design* run and the *Proposed Design* run ~~calculations.~~

ACM Joint Appendix II contains information about how to obtain the official CEC weather data. ~~The official hourly weather data for energy compliance is available from the Commission on 1.44 megabyte, 3.5 inch floppy diskettes (IBM PC format). There are 16 climate zones with a complete year of 8,760 hourly weather records. Each climate zone is represented by a particular city. More detail on the weather formats is given in the description package mailed with the weather tapes. The weather data may be obtained by mailing a written request for the weather data, a self-addressed diskette mailer, and three IBM-formatted 1.44 Megabyte diskettes to: RESACM Weather Data, Residential Office, California Energy Commission, 1516 Ninth Street MS#25, Sacramento, California 95814-5512.~~

Time Dependent Valuation (TDV) energy is the parameter used to compare the energy consumption of proposed designs to energy budgets. TDV replaces the source energy multipliers of one for natural gas and 3 for electric. TDV is explained in ACM Joint Appendix III in more detail.

4.1.2 4.11 Ground Reflectivity

~~Standard Design & Proposed Design:~~ ACMs shall assume that the ground surrounding residential buildings has a reflectivity of 20 percent in both summer and winter. This applies to both the *Standard Design* run and *Proposed Design* run.

4.1.3 4.4 Thermostats

~~Standard Design & Proposed Design:~~ The *standard* thermostat settings are shown in the ~~Table R 4-1~~ Table R4-1 below. The values for the "Whole House" ~~These thermostat setpoints~~ apply to the *Standard Design* run and are the default for the *Proposed Design* run. See the explanation later in this section regarding the values for Zonal Control.

~~Table R4-1~~ *Thermostat Settings*

	Cooling Mode	Heating Mode
Cooling Thermostat	78°F	78°
Heating Thermostat	60°F	68°F
Heating Setback	60°F	60°F
Ventilation Setpoints	68°F	77°F
Change over Temperature	60°F	60°F

It is assumed that the building has a constant cooling setpoint of 78°F. When the building is in a heating mode, the heating setpoint is 68°F with night setback to 60°F. The heating thermostat is set back from 11:00 pm until 7:00 am. During the summer or when the building is in a cooling mode, the heating setpoint is a constant 60°F.

The ventilation setpoint is 68°F when the building is in a cooling mode and 77°F when the building is in a heating mode. The state of the building's conditioning mode is dependent upon the outdoor temperature averaged over hours 1 through 24 of day 8 through day 2 prior to the current day. The ACM shall calculate and update daily this seven day running average of outdoor air temperature. When this average temperature is equal to or less than 60°F the building shall be set in a heating mode and all the thermostat setpoints for the heating mode shall apply. When the running average is greater than 60°F the building shall be set to be in a cooling mode and the cooling mode setpoints shall apply.

The standard heating and cooling setpoints are shown in Table 4-2 below for each hour of the day.

Table R4-1 – ~~Standard~~ Hourly Thermostat Set Points

Hour	<u>Whole House</u>		<u>Zonal Control Living Areas</u>		<u>Zonal Control Sleeping Areas</u>		Venting
	Heating	Cooling	Heating	Cooling	Heating	Cooling	
1	65	78	65 60	83	65 60	78	Off 68
2	65	78	65 60	83	65 60	78	Off 68
3	65	78	65 60	83	65 60	78	Off 68
4	65	78	65 60	83	65 60	78	Off 68
5	65	78	65 60	83	65 60	78	Off 68
6	65	78	65 60	83	65 60	78	68
7	65	78	65 60	83	65 60	78	68
8	68	83	68	83 78	68	83	68
9	68	83	68	83 78	65 60	83	68
10	68	83	68	83 78	65 60	83	68
11	68	83	68	83 78	65 60	83	68
12	68	83	68	83 78	65 60	83	68
13	68	83	68	83 78	65 60	83	68
14	68	82	68	82 78	65 60	83	68
15	68	81	68	81 78	65 60	83	68
16	68	80	68	80 78	65 60	83	68
17	68	79	68	79 78	65 60	83	68
18	68	78	68	78	65 60	83	68
19	68	78	68	78	65 60	83	68
20	68	78	68	78	65 60	83	68
21	68	78	68	78	65 60	83	68
22	68	78	68	78	68	78	68
23	68	78	68	78	68	78	68
24	65	78	65 60	83	65 60	78	68 Off

Determining Heating Mode vs. Cooling Mode. When the building is in the heating mode, the heating setpoints for each hour are set to the “Heating” values in Table R4-1-R, the cooling setpoint is set to a constant 78°F and the ventilation setpoint is set to a constant 77°F. When the building is in the cooling mode, the “Cooling” values are used. The heating setpoint is set to a constant 60°F, and the cooling and venting setpoints are set to the values in Table R4-1.

The state of the building's conditioning mode is dependent upon the outdoor temperature averaged over hours 1 through 24 of day 8 through day 2 prior to the current day (e.g., if the current day is June 21, the mode is based on the average temperature for June 13 through 20). The ACM shall calculate and update daily this 7-day running average of outdoor air temperature. When this running average temperature is equal to or less than 60°F the building shall be set in a heating mode and all the thermostat setpoints for the heating mode shall apply. When the running average is greater than 60°F the building shall be set to be in a cooling mode and the cooling mode setpoints shall apply.

Zonal Control: An optional capability, described in Section 6.2Chapter 6, allows alternative thermostat schedules to be used for the *Proposed Design* run when the HVAC system meets the requirements for zonal control. With zonal control, the building is divided into sleeping and living areas and a separate schedule is used for each area. If the user selects this option the ACM shall ~~select~~ use the appropriate alternative schedules based on the user's designations for sleeping and living zones and shall automatically report the use of this optional capability in the *Special Features and Modeling Assumptions* listings in the ~~required standard reports~~ CF1-R. The setpoints for zonal control are also shown in Table R4-1.

Setback Thermostat Exceptions. Certain types of heating and/or cooling equipment are ~~exempt~~ excepted from the mandatory requirement for setback thermostats, including wall furnaces and through-the-wall heat pumps. If setback thermostats are not installed, then the ACM shall model the *Proposed Design* with the standard

thermostat schedule, except that the heating mode setback setpoint shall be 66°F, ~~instead of 60°F~~. In cases where setback thermostats are not mandatory but nonetheless are installed by the builder, the ACM shall model the *Proposed Design* using the standard heating setback setpoint of 60°F. The *Standard Design* always assumes the setback schedule shown in Table R4-1 ~~Table R-4-2~~.

4.1.4 ~~4.5~~ Internal Gains

Basic Allocation ~~Standard Design & Proposed Design~~

Internal gain from lights, appliances, people and other sources shall be set to 20,000 Btu/day for each dwelling unit plus 15 Btu/day for each square foot of conditioned floor area (CFA) as shown in Equation R4-1.

$$\text{Equation R4-1} \quad \text{IntGain}_{\text{total}} = (20,000 \times N) + \left(15 \times \sum_{i=1}^N \text{CFA}_i \right)$$

Where

N = Number of dwelling units (~~NumDwellUnits~~)

CFA_i = Conditioned Floor Area of ith dwelling unit

Zonal Control

For zonal control, an optional modeling capability, the internal gains are split between the living areas and the sleeping areas as indicated in the following equations. The 20,000 Btu/day fixed component is assigned 100% to the living areas and the 15 Btu/ft² component is allocated according to floor area. See Equation R4-2 and Equation R4-3.

$$\text{Equation R4-2} \quad \text{IntGain}_{\text{Living}} = 15 \times \text{CFA}_{\text{Living}}$$

$$\text{Equation R4-3} \quad \text{IntGain}_{\text{Sleeping}} = 15 \times \text{CFA}_{\text{Sleeping}}$$

Additions

For addition-alone compliance (single-zone), the internal gains are apportioned according to the fractional conditioned floor area, referred to as the Fractional Dwelling Unit (FDU). For zone j, the internal gain is determined by Equation R4-4; ~~Equation 4.2~~:

$$\text{Equation R4-4} \quad \text{IntGainZone}_j = \text{IntGain}_{\text{tot}} \times \text{FDU}_j$$

where

~~_____ FDU_j =~~ Fractional Dwelling Unit of jth zone, calculated from Equation R4-5 ~~Equation 4.3~~

$$\text{Equation R4-5} \quad \text{FDU}_j = \frac{\text{CFA}_j}{\text{CFA}_{\text{total}}}$$

~~When zonal control is a feature of the Proposed Design for a single dwelling unit, the total internal gain is split between the living areas and the sleeping areas as described in Section 6.2.3, pg. 6-4~~

Building additions may be modeled in conjunction with the existing dwelling or modeled separately (see Sections 6.7.1 and 6.7.2 Chapter 6). When modeled together the number of dwelling units for the proposed dwelling (NDU_{proposed}) remains equal to the number of dwelling units for the existing structure (NDU_{existing}), while the conditioned floor area (CFA_{proposed}) is increased to include the contribution of the addition (CFA_{addition}). When modeled separately, the internal gain of the addition ($IntGain_{\text{addition}}$) is based on the value of the addition's fractional dwelling unit (FDU_{addition}), as expressed in Equation R4-6 and Equation R4-7. Equations 4.4 and 4.5.

Modeling additions is an optional capability described in Section 6.7, Page 6-17.

Equation R4-6

$$IntGain_{\text{addition}} = IntGain_{\text{total}} \times FDU_{\text{addition}}$$

where

Equation R4-7

$$FDU_{\text{addition}} = \frac{CFA_{\text{addition}}}{CFA_{\text{existing}} + CFA_{\text{addition}}}$$

Hourly 4.6 Internal Gain Schedules

Standard Design & Proposed Design For hourly computer models, the The standard hourly internal gain schedule is shown in Table R4-2 Table R 4-4 applies. "Hour one" is between midnight and 1:00 am. This The whole building schedule shall always be used for the *Standard Design* run. The whole building is also used It is the default for the *Proposed Design* run and shall be used unless the *Proposed Design* has zonal control. For zonal control, the Living Areas schedule is used for the living areas and the Sleeping Areas schedule is used for sleeping areas. assumptions, see Chapter 6, Section 6.2.

Table R4-2 – Hourly Internal Gain Schedules

Hour	Percent of Daily Total Internal Gains (%)		
	Whole House	Living Areas	Sleeping Areas
1	2.40	<u>1.61</u>	<u>4.38</u>
2	2.20	<u>1.48</u>	<u>4.02</u>
3	2.10	<u>1.14</u>	<u>4.50</u>
4	2.10	<u>1.13</u>	<u>4.50</u>
5	2.10	<u>1.21</u>	<u>4.32</u>
6	2.60	<u>1.46</u>	<u>5.46</u>
7	3.80	<u>2.77</u>	<u>6.39</u>
8	5.90	<u>5.30</u>	<u>7.40</u>
9	5.60	<u>6.33</u>	<u>3.76</u>
10	6.00	<u>6.86</u>	<u>3.85</u>
11	5.90	<u>6.38</u>	<u>4.70</u>
12	4.60	<u>5.00</u>	<u>3.61</u>
13	4.50	<u>4.84</u>	<u>3.65</u>
14	3.00	<u>3.15</u>	<u>2.63</u>
15	2.80	<u>2.94</u>	<u>2.46</u>
16	3.10	<u>3.41</u>	<u>2.32</u>
17	5.70	<u>6.19</u>	<u>4.47</u>
18	6.40	<u>7.18</u>	<u>4.45</u>
19	6.40	<u>7.24</u>	<u>4.29</u>
20	5.20	<u>5.96</u>	<u>3.30</u>
21	5.00	<u>5.49</u>	<u>3.75</u>
22	5.50	<u>6.20</u>	<u>3.75</u>
23	4.40	<u>4.38</u>	<u>4.45</u>
24	2.70	<u>2.35</u>	<u>3.59</u>
Total	100.00	100.00	100.00

Seasonal Adjustments

Daily internal gain shall be modified each month according to the set of multipliers shown in Table R4-3Table 4-5. These multipliers are derived from the number of daylight hours for each month.

Table R4-3 – Seasonal Internal Gain Multipliers

Month	Multiplier	Month	Multiplier	Month	Multiplier
Jan	1.19	May	0.84	Sep	0.98
Feb	1.11	Jun	0.80	Oct	1.07
Mar	1.02	Jul	0.82	Nov	1.16
Apr	0.93	Aug	0.88	Dec	1.21

4.2 Heat Gains and Losses Through Opaque Surfaces

4.2.0 Absorptivity

Standard Design: In the *Standard Design* run, the absorptivity of all surfaces is assumed to be the same as the *Proposed Design*.

Proposed Design: In the *Proposed Design*, the absorptivity of walls or other surfaces adjacent to unconditioned spaces, such as crawl space floors and walls adjacent to attached garages, may be assumed to be zero, otherwise all surfaces shall be assumed to have an absorptivity of 0.50.

4.2.1 4.2.4 Radiant Barriers

Algorithm

Standard Design: The *Standard Design* has a radiant barrier in accordance with Package D requirements.

Proposed Design: The benefits of radiant barriers are modeled in two ways. First, the U -factor is modified for each season (heating mode and cooling mode) to account for reduced heat gain (attics are not modeled as separate unconditioned thermal zones in residential ACMs). Second, modifiers that are functions of the ceiling insulation and the season and by using different the seasonal attic temperatures for attics are lower with radiant barriers, which results in better HVAC distribution efficiencies for ducts located in the attic below a radiant barrier. See the algorithms for HVAC air distribution ducts for more details. When the building is in a heating mode, (see Section 4.1.3), Equation Equation R4-8 is provides the expression for the U -factor modifier due to the presence of a radiant barrier. When the building is in a cooling season mode, Equation Equation R4-9 is used. To determine the U -factor for a ceiling with a radiant barrier, multiply the U -factor of the ceiling assembly without located beneath a the radiant barrier times the U -factor modifier. The U -value modifiers are calculated from equations and . These modifiers may only be used for

For installed insulation greater than R-8, otherwise the modifier is 1.00.:

$$\text{Equation R4-8} \quad U_{\text{factor}} \text{Mod}_{\text{heating}} = (-11.404 \times U^2) + (0.21737 \times U) + 0.92661$$

$$\text{Equation R4-9} \quad U_{\text{factor}} \text{Mod}_{\text{cooling}} = (-58.511 \times U^2) + (3.22249 \times U) + 0.64768$$

Otherwise these modifiers are 1.000.

Eligibility Criteria

Radiant barriers must shall meet specific eligibility and installation criteria to be modeled by any ACM and receive energy credit for compliance with the energy efficiency standards for low-rise residential buildings.

- The emittance of the radiant barrier must shall be less than or equal to 0.05 as tested in accordance with ASTM C-1371-978 or ASTM E408-74(1996)e1.
- Installation must shall be in conformance with to ASTM C-1158-97 (Standard Practice For Use and Installation Of Radiant Barrier Systems (RBS) In Building Construction.), ASTM C-727-90(1996)e1 (Standard Practice For Installation and Use Of Reflective Insulation In Building Constructions.), ASTM C1313-975 (Standard Specification for Sheet Radiant Barriers for Building Construction Applications), and ASTM C-1224-993 (Standard Specification for Reflective Insulation for Building Applications), and the radiant barrier must shall be securely installed in a permanent manner with the shiny side facing down toward the interior of the building (ceiling or attic floor). Moreover, radiant barriers must shall be installed to at the top chords of the roof truss/rafters (top chords) in **any** of the following methods, with the material:

1. Draped over the truss/rafter (the top chords) before the upper roof decking is installed.
2. Spanning between the truss/rafters (top chords) and secured (stapled) to each side.
3. Secured (stapled) to the bottom surface of the truss/rafter (top chord). A minimum air space mustshall be maintained between the top surface of the radiant barrier and roof decking of not less than 1.5 inches at the center of the truss/rafter span.
4. Attached [laminated] directly to the underside of the roof decking. The radiant barrier mustshall be laminated and perforated by the manufacturer to allow moisture/vapor transfer through the roof deck.

In addition, the radiant barrier mustshall be installed to cover all gable end walls and other vertical surfaces in the attic.

- The attic mustshall be ventilated to:
 1. ~~conform~~ Conform to the radiant barrier manufacturer's instructions.
 2. ~~provide~~ Provide a minimum free ventilation area of not less than one square foot of vent area for each 150 square feet of attic floor area.
 3. ~~provide~~ Provide no less than 30 percent upper vents.

(Ridge vents or gable end vents are recommended to achieve the best performance. The material should be cut to allow for full airflow to the venting.)
- The radiant barrier (except for radiant barriers laminated directly to the roof deck) mustshall be installed to have a minimum gap of 3.5 inches between the bottom of the radiant barrier and the top of the ceiling insulation to allow ventilation air to flow between the roof decking and the top surface of the radiant barrier have a minimum of six (6) inches (measured horizontally) left at the roof peak to allow hot air to escape from the air space between the roof decking and the top surface of the radiant barrier.
- When installed in enclosed rafter spaces where ceilings are applied directly to the underside of roof rafters, a minimum air space of 1 inch mustshall be provided between the radiant barrier and the top of the ceiling insulation, and ventilation mustshall be provided for every rafter space. Vents mustshall be provided at both the upper and lower ends of the enclosed rafter space.
- The product mustshall meet all requirements for California certified insulation materials [radiant barriers] of the Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, as specified by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.
- The use of a radiant barrier ~~and the criteria specified above for covering all gable end walls and other vertical surfaces in the attic, and for providing attic ventilation shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and C-2R and described in detail in the ACM Compliance Supplement.~~

4.2.2 4.25-Cool Roofs

Algorithm

~~Standard Design:~~ ~~The Standard Design does not have a cool roof.~~

~~Proposed Design:~~ ~~Cool roofs are assumed modeled to have an impact equal to the cooling savings for radiant barriers. The calculations for cool roofs are the same as radiant barriers, are the same as described in section 4.24 except that $U_{facval}Mod_{heating}$ (see Equation R4-8 equation —) is assigned a value of 1.00. In the event that both a cool roof and radiant barrier is are specified, there is no credit for the cool roof.~~

Eligibility Criteria

Cool roofs mustshall meet specific eligibility and installation criteria to receive ~~energy~~ credit for compliance ~~as described in the standards and this section. In general, the solar reflectance mustshall be 0.4 or higher for tile roofs or 0.7 or higher the for other roof materials; and the emittance mustshall be 0.75 or higher. Liquid applied~~

cool roof products shall meet the requirements of Section 118(i)3 of the standards. All products qualifying for this credit shall be rated and labeled by the Cool Roof Rating Council in accord with Section 10-113 of the standards. The use of a cool roof shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and C-2R and described in detail in the ACM Compliance Supplement.

Liquid-applied roofing products shall be applied at a minimum dry mil thickness of 20 mils across the entire roof surface, and meet the minimum performance requirements of ASTM D6083-97a when tested in accordance with ASTM D6083-97a for the following key properties:

* Initial Tensile Strength

* Initial Elongation

* Elongation After 1000 Hours Accelerated Weathering

* Permeance

* Accelerated Weathering

Effective January 1, 2003, all products qualifying for this credit will be required to meet the Cool Roof Rating Council testing, certification and labeling requirements described in Section 10-113 of the standards. Prior to January 1, 2003, the solar reflectance shall be measured in accordance with ASTM E1918-97 or ASTM E903-96. Emittance shall be measured in accordance with ASTM E408-71(1996)e1. The solar reflectance and emittance shall be certified by the manufacturer and reported in product literature.

4.2.3 4.2-R-Value/U-Value/U-factor Determinations and Calculations

According to the Standards, the R-value of a material is "the [thermal] resistance of a material or building component to the passage of heat in (hr x ft² x °F)/Btu."

The R-value indicates how well a material prevents heat from flowing through it. R-19 insulation, for example, is only half as effective at slowing heat transfer as R-38 insulation.

Overall thermal resistances (overall R-values) and overall thermal transmittance values (overall U-value/U-factors) shall be calculated/determined from ACM Joint Appendix IV, using algorithms and methods consistent with the algorithms and methods in the 1997 ASHRAE Handbook of Fundamentals, Chapters 22, 23 and 24. For construction assemblies or portions of construction assemblies that consist of two or more plane parallel layers of materials in series (such as exterior siding, insulation and interior gypsum board), the thermal resistance of the assembly is equal to the sum of the individual thermal resistances. When layers are penetrated or interrupted by wood framing or other framing elements that do not readily conduct heat, the parallel path method shall be used to calculate the R-value and U-value of the construction assembly. Standard framed (wood and metal) walls with studs 16 in. on center shall be modeled to have 25% framing, and standard framed walls with studs located at 24 in. centers shall be modeled to have 22% framing. When metal framing is used or construction layers are penetrated by other significant amounts of highly heat conductive materials such as metals, the zonal calculation method, modified zonal calculation method, finite element or finite difference methods, or the Commission's EZ frame computer program must be used to determine overall R-value and overall U-value.

Most typical constructions can be calculated using the parallel path method and documented using the residential compliance Form 3R.

The U-value is the inverse of the total R-value:

$$\text{Equation 4.10} \quad U = \frac{1}{R_{\text{Total}}}$$

Degree of Precision:

The U-value is the heat transfer coefficient expressed in Btu/ft² · hr · °F, the rate at which heat flows through an assembly or material.

The total R-value shall be entered, stored, displayed, and calculated to at least three significant figures, or, alternatively to two decimal places, and the total U-value/U-factor to two significant figures or three decimal places whichever is more precise.

4.2.1 Default R-values/U-values in Appendix E

Data from ACM Joint Appendix E-IV contains pre-calculated Form 3Rs for a number of standard assemblies. ~~The Total R-values and U-values from these assemblies must~~shall be used in compliance calculations unless the CEC approves alternate values through the exceptional methods process. ~~a Form 3R is completed for the actual proposed assembly, or unless the compliance approach only uses the insulation level alone. Table E-7 in Appendix E summarizes these default U-values.~~

Appendix IV also includes pre-calculated assemblies that meet the default U-factors using a combination of batt and rigid insulation. Steel framing assemblies are also included. Appendix IV has R-values for common materials; information on a variety of masonry wall assemblies; and other data useful in determining the U-factor of an assembly.

Appendix E also includes Form 3Rs for assemblies that meet the default U-values with a combination of batt and rigid insulation, rather than only batt insulation (including metal frame assemblies). In addition, it contains R-values and other information on a variety of masonry wall assemblies.

To determine if an assembly meets the minimum insulation levels required by the mandatory measures or the prescriptive packages, obtain the U value of the proposed assembly or complete a Form 3R and see if the proposed U value is less than or equal to the standard U value for that assembly type and insulation level as listed in Table 3-1 in Chapter 3 and Table E-2 in Appendix E. Compare the proposed U value to the U values listed for framing spacing of 16" o.c. for walls and 24" o.c. for roofs/ceilings.

4.2.4 Insulation Installation Quality

Compliance credit is available for low-rise residential buildings if field verification is performed to ensure that quality insulation and air barrier installation procedures are followed (see ACM RH-2005). All newly insulated opaque surfaces in a building must be field verified to receive this credit. Compliance reports and user interfaces shall identify the building as having either *Standard* or *Improved* insulation installation quality. As discussed in Chapter 3, the *Standard Design* shall have standard insulation installation quality. Approved ACMs must be able to model both *Standard* and *Improved* insulation installation quality (see Table R4-4).

Table R4-4 – Modeling Rules for insulation installation Quality

Component	Mode	insulation installation Quality	
		Standard	Improved
Walls	Both	Increase heat gains and losses by 19%, i.e., multiply all wall U-factors by 1.19.	Increase heat gains and losses by 5%, i.e., multiply all wall U-factors by 1.05.
Ceilings/Roofs	Heating	Add 0.02 times the area to the UA of each ceiling surface i.e., add 0.02 to the U-factor.	Add 0.01 times the area to the UA of each ceiling surface i.e., add 0.01 to the U-factor.
	Cooling	Add 0.005 times the area to the UA of each ceiling surface i.e., add 0.005 to the U-factor.	Add 0.002 times the area to the UA of each ceiling surface i.e., add 0.002 to the U-factor.

When credit is taken for Improved insulation installation quality, the *Field Verification and Diagnostic Testing* section of the CF-1R shall show that field verification is required (see Chapter 2) and the Installation Certificate (CF-6R) and the Field Verification and Diagnostic Testing Certificate (CF-4R) must be completed and signed by the installer and HERS Rater, respectively.

4.2.5 4.7.1 Perimeters of Slab Floors and Carpeted Slabs

~~Standard Design & Proposed Design:~~ For *Standard* and *Proposed Designs* all ACMs ~~must~~shall use slab edge F2 values assuming that 20% of the slab floor perimeter is exposed to the conditioned air and 80% of the

slab floor perimeter is carpeted or covered with an R-2 insulating layer between the slab and the conditioned air. See ACM Joint Appendix IV.

The monthly ground temperatures shown in Table R4-56 shall be used as the exterior temperature when calculating slab edge heat loss.

Table R4-5 – Monthly and Annual Average Ground Temperatures

Climate Zone	Month												Annual Average
	J	F	M	A	M	J	J	A	S	O	N	D	
1	52.2	51.5	51.4	51.8	53.1	54.5	55.6	56.4	56.4	55.8	54.7	53.4	53.9
2	53.3	51.5	51.4	52.2	55.6	58.9	61.8	63.6	63.8	62.3	59.5	56.3	57.5
3	55.1	54.1	54.0	54.5	56.5	58.5	60.3	61.4	61.5	60.6	58.9	56.9	57.7
4	55.5	54.0	53.9	54.6	57.5	60.3	62.8	64.3	64.5	63.2	60.8	58.0	59.1
5	55.7	54.8	54.7	55.2	56.9	58.7	60.2	61.1	61.2	60.4	59.0	57.3	57.9
6	59.1	58.1	58.0	58.5	60.4	62.4	64.0	65.1	65.2	64.3	62.7	60.8	61.6
7	60.1	59.1	59.0	59.5	61.5	63.4	65.2	66.2	66.3	65.5	63.8	61.9	62.6
8	60.0	58.8	58.7	59.2	61.6	63.9	66.0	67.3	67.4	66.3	64.3	62.1	63.0
9	60.5	59.1	59.0	59.7	62.2	64.8	67.1	68.5	68.6	67.5	65.3	62.8	63.8
10	59.4	57.6	57.4	58.3	61.8	65.2	68.2	70.1	70.2	68.7	65.8	62.4	63.8
11	54.9	52.4	52.2	53.4	58.2	63.0	67.2	69.8	70.0	67.9	63.8	59.2	61.0
12	54.6	52.5	52.3	53.3	57.3	61.3	64.8	67.0	67.2	65.4	62.0	58.1	59.7
13	57.5	54.7	54.5	55.8	61.0	66.2	70.6	73.5	73.7	71.4	67.0	62.0	64.0
14	54.2	51.2	51.0	52.4	58.2	63.9	68.8	72.0	72.2	69.7	64.8	59.3	61.5
15	66.8	64.0	63.8	65.1	70.4	75.8	80.4	83.3	83.6	81.2	76.7	71.5	73.6
16	44.4	41.8	41.6	42.8	47.7	52.6	56.8	59.5	59.7	57.5	53.4	48.7	50.5

Standard Design: The slab perimeter shall be assumed to have an F2 value based on perimeter insulation as specified for Alternative Component Package D in Section 151 of the building efficiency standards. The Standard Design also assumes that no unconditioned spaces are attached to the conditioned space (in particular that the garage is detached), hence the total slab perimeter length is either insulated or uninsulated per the requirements of Alternative Component Package D. Hence, for the Standard Design, the slab edge heat loss factor, F2, is 0.76 for all climate zones except Climate Zone 16 where F2 is 0.51.

Proposed Design: Slab perimeter insulation shall be modeled using an F2 factor for the insulation to be installed and the perimeter length that is to be insulated. The slab perimeter length adjacent to unconditioned spaces such as a garage may be modeled as an R-7 insulated perimeter with an F2 factor of 0.51.

4.2.6 4.3 Basement Modeling - Basement Walls and Floors

Below grade walls shall be modeled with have no exterior absorptivity (no radiant no solar gains, i.e., absorptivity is zero, from sunlight). Below grade walls are modeled with three exterior conditions depending on whether the depth is shallow, medium, or deep. The temperature of the earth depends on the depth of the wall and is given in Table R4-6. Thermal resistance also shall be increased to account for earth near the construction (see Table R4-6).

Table R4-6 – Earth Temperatures for Modeling Basement Walls and Floors

<u>-Class</u>	<u>Depth</u>	<u>Assumed Temperature of the Earth</u>	<u>Thermal Resistance of Earth</u>
<u>Shallow Depth Walls</u>	<u>Up to 2 ft</u>	<u>Average air temperature for hours 1 through 24 of the 7 days beginning 8 days prior to the current day (days -8 through -2).</u>	<u>A thermal resistance with an R-value of 1.57 (hr.ft².°F/Btu) is added to the outside of the below grade wall.</u>
<u>Medium Depth Walls</u>	<u>2+ to 6 ft</u>	<u>Exterior earth temperature is assumed to be the monthly average temperature from Table R4-5.</u>	<u>A thermal resistance with an R-value of 7.28 (hr.ft².°F/Btu) is added to the outside of the below grade wall.</u>
<u>Deep Walls</u>	<u>More than 6 ft</u>	<u>Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R4-5.</u>	<u>A thermal resistance with an R-value of 13.7 (hr.ft².°F/Btu) is added to the outside of the below grade wall.</u>
<u>Basement Floors</u>	<u>Any</u>	<u>Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R4-5.</u>	<u>A thermal resistance with an R-value of 17.6 (hr.ft².°F/Btu) is added to the bottom of the basement floor.</u>

4.3.1 Shallow Depth Walls

The first two feet (inclusive) of the below grade wall uses the average air temperature for hours 1 through 24 of the 7 days beginning 8 days prior to the current day (days -8 through -2). In addition, a thermal resistance with an R-value of 1.57 (hr.ft².°F/Btu) is added between this average temperature and the outside of the below grade wall.

4.3.2 Medium Depth Walls

The basement walls from more than 2 feet below grade through 6 feet below grade have an exterior temperature that is the average of hours 1 through 24 of the 7 days of outdoor temperature from the period starting 68 days prior to the current day being simulated through 62 days prior to the first hour of the current day being simulated. In addition, a thermal resistance with an R-value of 7.28 (hr.ft².°F/Btu) is added between this lagged average temperature and the outside of the below grade wall.

4.3.3 Deep Walls and Floors

Walls more than 6 feet below grade and basement floors have an exterior temperature that is typical of deep ground temperatures. These temperatures are given in Table R 4-3 below for each of the sixteen climate zones. In addition, a thermal resistance with an R-value of 13.7 (hr.ft².°F/Btu) is added between this average temperature and the outside of the below grade wall. For basement floors this added R-value is 17.6 hr.ft².°F/Btu.

~~Table R4-5 Temperatures for Deep Walls and Floors by Climate Zone~~

Climate Zone	Deep Ground Temperature
1	49.1
2	64.5
3	62.8
4	61.4
5	56.8
6	64.1
7	61.6
8	63.9
9	66.4
10	68.9
11	69.5
12	67.8
13	67.6
14	68.6
15	74.6
16	54.1

4.3 Heat Gains and Losses Through Fenestration

4.3.1 ~~4.23~~ Fenestration Products

Information concerning fenestration products, specifically the default table for fenestration U-valueU-factors and the default table for fenestration SHGC values, is included in Sections 401 and 116 of Title 24, Part 6, the energy efficiency standards for buildings.

4.3.2 ~~4.16~~ Solar Gain

Solar gain through glazing shall be calculated using the methods documented in the *Algorithms and Assumptions Report, 1988*. ~~This method is modified, however, for the standards effective after 1998.~~ However, solar gain through windows is reduced to 72.67.5 percent of the full solar gain and a new algorithm is used to calculate the transmitted solar gain as a function of the angle of incidence on the glazing. The 0.6752 reduction multiplier is intended to compensate for exterior shading from landscaping, terrain, and adjacent buildings, as well as dirt and other window obstructions.

The ~~formulas equations~~ used to calculate the solar heat gain through windows as a function of the angle of incidence are given below in the form of two multipliers: - G_{dir} - the ratio of the solar heat gain to the space relative to direct beam insolation at normal incidence, and G_{dif} - the ratio of solar heat gain to the space relative to the diffuse insolation on a horizontal surface. These ratios ~~have no units of measure~~ are unitless.

$$\text{Equation R4-10} \quad G_{dir} = SHGC_{fen} * Area * [fsunlit * CosI * P(CosI) + GrndFac]$$

and

$$\text{Equation R4-11} \quad G_{dif} = SHGC_{fen} * Area * DMSHGC * (vfSky + vfGrnd * GrndRf)$$

where

$$\text{Equation R4-12} \quad P(\text{Cos}I) = C1 * \text{Cos}I + C2 * \text{Cos}^2I + C3 * \text{Cos}^3I + C4 * \text{Cos}^4I$$

$$\text{Equation R4-13} \quad \text{GrndFac} = \text{vfGrnd} \times \text{CosG} \times \text{GrndRf} \times \text{DMSHGC}$$

$SHGC_{fen}$ = ___ Fenestration Solar Heat Gain Coefficient at normal beam incidence - primary user input [unitless]

$\text{Cos}I$ = ___ The cosine of the angle of incidence of the direct beam insolation on the window. [unitless]

CosG = ___ The cosine of the angle of incidence of the direct beam insolation on the ground. [unitless]

DMSHGC = ___ Diffuse Multiplier for Solar Heat Gain Coefficient [unitless]

fsunlit = ___ Fraction of the window sunlit by direct beam at this hour [unitless]

$C1, \dots, C4$ = ___ Polynomial coefficients for angular dependence (cosine of the angle of incidence) of solar heat gain - see Table R4-7

vfSky = ___ View factor of window to sky [unitless]

vfGrnd = ___ View factor from window to ground [unitless]

GrndRf = ___ Ground Reflectance [unitless] = 0.20

Table R4-7 – Polynomial Coefficients for Angular Dependence

Glazing Type:	Single Pane (1 light)	More Than One Pane (2 or more lights)
$SHGC_{fen}$	0.860	0.695
C1	3.549794	1.881643
C2	-4.597536	1.014431
C3	2.432124	-4.009235
C4	-0.384382	2.113160
DMSHGC	0.905814	0.828777

4.3 Shading Calculations

4.3.3 4.4.1 Interior Shading and Exterior Shading Sunscreen Operation

Standard Design & Proposed Design: The standard assumptions for operation of interior shading devices and sunscreens shall apply to both the *Standard Design* run and the *Proposed Design* run.

Draperies are assumed to be closed only for hours when the air conditioner operates. To approximate this affect during transitions between periods of operation and non-operation, ACMs may assume that the internal device remains closed for the hour following the period an hour of air conditioner operation. As soon as that hour passes, the internal shading device shall be opened unless the air conditioner continues to run. The internal device shall be either totally open or totally closed for any given hour.

External sunscreens are assumed to be in place all year, whether the building is in a heating or cooling mode.

The shading effects of overhangs, side fins and other fixed shading devices are determined hourly, based on the altitude and azimuth of the sun for that hour, the orientation of the fenestration, and the relative geometry of the fenestration and the fixed shading devices.

The standard assumptions for operation of interior shading devices and sunscreens shall apply to both the *Standard Design* and the *Proposed Design*.

4.3.4 ~~4.4.2~~ Solar Heat Gain Coefficients

Solar Heat Gain Coefficients shall be determined according to Chapter 3 of this manual. ~~ACMs use two values for setting the solar heat gain coefficient values of shading devices: "SHGC_{open}" and "SHGC_{closed}." "SHGC_{open}" applies when the air conditioner is not in operation (off) and "SHGC_{closed}" applies when the air conditioner is in operation. The ACM user shall not be allowed to enter values for SHGC_{open} and SHGC_{closed}. These values must be automatically calculated from the specification of the SHGC for the fenestration (SHGC_{fen}), the exterior shade and the interior shade as described below. ACMs shall forbid users from direct entry of SHGCs for interior and exterior shading devices. The ACM must shall automatically determine these values from the user's choices of exterior shading devices and from the assumption that vertical glazing has a drapery and non-vertical (skylight) glazing has no interior shading device.~~

There are a limited set of shading devices with fixed prescribed characteristics that are modeled in the performance approach. These devices and their associated fixed solar heat gain coefficients are listed in ~~Table R-3-2 and Table R-3-3~~ Table R3-5 and Table R3-7.

The formula for combining solar heat gain coefficients is:

$$\text{Equation R4-14} \quad \text{SHGC}_{\text{comb}} = [(0.2875 \times \text{SHGC}_{\text{max}}) + 0.75] \times \text{SHGC}_{\text{min}}$$

where

$\text{SHGC}_{\text{comb}}$ = the combined solar heat gain coefficient for a fenestration component and an attachment in series.

SHGC_{max} = the larger of SHGC_{fen} and SHGC_{dev}

SHGC_{min} = the smaller of SHGC_{fen} and SHGC_{dev}

where

SHGC_{fen} = the solar heat gain coefficient of the fenestration which includes the window glazing, transparent films and coatings, and the window framing, dividers and muntins,

SHGC_{dev} = the solar heat gain coefficient of the interior or exterior shading device when used with a metal-framed, single pane window.

For $\text{SHGC}_{\text{closed}}$, the combination SHGC, $\text{SHGC}_{\text{fen+int}}$, (the combined SHGC for the fenestration and the interior device) is calculated first and then the combination $\text{SHGC}_{\text{fen+int+ext}}$ is calculated to determine the overall $\text{SHGC}_{\text{closed}}$. $\text{SHGC}_{\text{open}}$ is determined from the combination of SHGC_{fen} and SHGC_{ext} .

~~The combination $\text{SHGC}_{\text{fen+int}}$ is calculated as above for the *Standard Design* when the Package D specification for SHGC is No Requirement with SHGC = NR (No Requirement) set to a default SHGC of 0.70, which is typical of a double pane, metal framed window.~~

~~$$\text{SHGC}_{\text{fen+int}} = [(\text{SHGC}_{\text{fen}} \times 0.2875) + 0.75] \times \text{SHGC}_{\text{drap}}$$~~

or

~~$$\text{SHGC}_{\text{fen+int}} = [(0.70 \times 0.2875) + 0.75] \times 0.68 = [0.95125] \times 0.68 = 0.64685$$~~

~~With the effects of the exterior shade,~~

~~$$\text{SHGC}_{\text{fen+ext}} = [(\text{SHGC}_{\text{ext}} \times 0.2875) + 0.75] \times \text{SHGC}_{\text{fen+int}}$$~~

or

~~$$\text{SHGC}_{\text{closed}} = \text{SHGC}_{\text{fen+int+ext}} = [(0.76 \times 0.2875) + 0.75] \times 0.64685$$~~

~~$$= [0.9685] \times 0.64685 = 0.626 \quad \text{and}$$~~

$$\begin{aligned} \text{SHGC}_{\text{open}} &= \text{SHGC}_{\text{fen+ext}} = [(0.76 \times 0.2875) + 0.75] \times 0.70 \\ &= [0.9685] \times 0.70 = 0.678 \end{aligned}$$

4.4 Thermal Mass^{4.7}

ACMs shall be capable of modeling thermal mass in buildings. Thermal mass has the ability to store heat and thus damp temperature fluctuations in the conditioned space. There are two types of thermal mass, *Light Mass* which reacts very quickly to absorb or release heat, and *Heavy Mass* which reacts more slowly. *Light Mass* is **Standard Design & Proposed Design**: Thermal mass is modeled in the same way for in both the *Proposed Design* and the *Standard Design*. The modeled mass includes the basic common elements thermal mass such as framing, furniture, 0.5½ in. sheetrock gypsum board, and household appliances. as “light” mass elements. Light mass is modeled through an input in the reference program called building heat capacity and is assumed to be fixed at 3.5 Btu/°F-ft² of conditioned floor area for both the *Proposed Design* and the *Standard Design*. Other values may be used for unconditioned zones (see Chapter 6).

and specific “heavy Heavy” mass includes elements such as concrete slab floors, masonry walls, double gypsum board and other special mass elements. When the *Proposed Design* qualifies as a high mass building then each element of heavy mass is modeled in the *Proposed Design*, otherwise, the *Proposed Design* is modeled with the same hThis modeled thermal mass has the ability to store heat and thus damp temperature fluctuations in the conditioned space. The *Proposed Design* and the *Standard Design* must have the same “light” mass elements and for most dwellings the *Standard* and *Proposed Designs* will also have and model the same “heavy” mass elements. eavy thermal mass as the *Standard Design*. See Chapter 3 for details on what qualifies as a high mass building. The default thermal mass for the *Proposed Design* and the fixed thermal mass for the *Standard Design* is based on 20% of the slab floor being exposed and 80% covered with carpet or casework. In addition 5% of the non-slab floor is exposed with a topping of 2 in. of concrete. ACM RB-2005 has procedures for quantifying the value of various types of thermal mass.

ACMs must assume that both the *Proposed Design* and *Standard Design* building have a certain amount of minimum “heavy” thermal mass as a function of the conditioned area of slab floor and conditioned nonslab floor. Unless the *Proposed Design* has thermal mass that exceeds a thermal mass minimum threshold, the modeled thermal mass for both the *Proposed Design* and the *Standard Design* is 20% of the *Proposed Design*'s conditioned slab floor area as exposed slab, 80% of the conditioned slab floor area as rug-covered slab, and 5% of the *Proposed Design*'s conditioned nonslab floor area as exposed 2 inch thick concrete.

The modeled exposed slab floor has the following default characteristics: a thickness of 3.5 inches, a volumetric heat capacity of 28 Btu/ft³ °F, a conductivity of 0.98 Btu in/hr ft² °F, a surface conductance of 1.3 Btu/hr ft² °F (no thermal resistance on the surface). The remaining 80% of the conditioned slab floor shall be modeled as covered thermal mass with the same characteristics as the exposed mass, but with the addition of a surface R value of 2.0 (hr ft² °F)/Btu typical of a carpet and pad.

Conditioned nonslab floor area shall be modeled with 5% of the nonslab floor area as exposed thermal mass. This thermal mass is modeled in the *Standard Design* with a thickness of 2.0 inches, a volumetric heat capacity of 28 Btu/ft³ °F, a conductivity of 0.98 Btu in/hr ft² °F, a surface conductance of 1.3 Btu/hr ft² °F (no added thermal resistance on the surface). The ACM must also model it this way in the *Proposed Design* unless the *Proposed Design* exceeds the thermal mass threshold. The ACM may also require that the user specify a “high mass” or “passive solar” option before allowing the entry of special mass elements and the modeling of thermal mass when the total thermal mass exceeds the high mass threshold.

Proposed Design: The *Proposed Design* may model additional thermal mass when the user selects the ACM's “high mass” building input option by modeling thermal mass in excess of the assumed thermal mass for the *Standard Design* when the equivalent design thermal mass for the *Proposed Design* reaches or exceeds a specific mass threshold. This threshold is determined by the amount of thermal mass equivalent to 30% of the conditioned slab floor area as exposed 3.5” thick concrete slab, 70% of the conditioned slab floor area as rug-covered 3.5” thick concrete slab and 15% of the conditioned raised floor area as 2 inch thick exposed concrete with the same specifications as those given above. To determine the threshold, this mass is converted to a

standard Interior Mass Capacity using the Unit Interior Mass Capacity (UIMC) method described in Appendix I and compared to the design mass to determine if the mass threshold is exceeded.

4.9 Building Heat Capacity

Standard Design & Proposed Design: The heat capacity associated with conventional framed construction includes 1/2 inch gypsum board, wall framing and building contents. The building heat capacity is assumed to be fixed at 3.5 Btu/°F per square foot of conditioned floor area. Other values may be used for unconditioned zones (see Chapter 6).

The assumed value shall apply to the *Standard Design* and shall be the default for the *Proposed Design*.

Proposed Design: The value may be adjusted in the *Proposed Design* run for a user-designated high mass design for special building features such as extra thick gypsum board or heavy mass elements. For such calculations, the surface area of gypsum board shall be assumed to be four times the conditioned floor area. The compliance supplement shall contain recommendations for modifying the building heat capacity, when applicable, and the ACM shall identify the variation in building heat capacity as a special feature of the building. This shall be noted in the "*Special Features and Modeling Assumptions*" listings of the standard reports.

4.8 Solar Gain Targeting. Standard Design & Proposed Design: Solar gains from windows or skylights shall not be targeted to mass elements within the conditioned space of the building. In the reference program, CALRES, all solar gain is targeted to the air or a combined air-and lightweight, high surface area mass node within the building. This modeling assumption is used in both the *Standard Design* run and the *Proposed Design* run, except for sunspaces where the user has flexibility in targeting solar gains subject to certain constraints. Sunspace modeling is an optional capability discussed in Section 6.3 Chapter 6.

Unconditioned Sunspaces. For compliance purposes, when glazing surfaces enclose unconditioned spaces, such as sunspaces, the user is allowed to target all but 25% of the solar gains from these surfaces to Heavy mass elements located within the unconditioned space. Unassigned solar gain is targeted to the air or the combined air/lightweight mass or to high surface area lightweight mass in the unconditioned space. At least 25% of the solar gain from any sunspace fenestration surface ~~must~~shall be targeted to high surface area lightweight mass and/or the air. At most 60% of the solar gain may be targeted to the slab floor of a sunspace, especially in the summer. For compliance purposes, an ACM ~~must~~shall automatically enforce these limits and inform the user of any attempt to exceed these limits.

4.5 Infiltration and Natural Ventilation

4.4.14.5.1 Infiltration/Ventilation

The reference method uses the effective leakage area method for calculating infiltration in conditioned zones. Calculations shall use Shielding Class 4 as defined in the 2001 ASHRAE Handbook of Fundamentals.

Default Specific Leakage Area. The default specific leakage area (SLA) is 4.9 for designs with ducted HVAC systems and 3.8 for non-ducted HVAC systems. The default is always used for the *Standard Design*. The *Proposed Design* may use an alternate value, but only with diagnostic testing. The specific leakage area (SLA) is the ratio of the effective leakage area to floor area in consistent units. The value is then increased by 10,000 to make the number more manageable. If the effective leakage area (ELA) is known in inches, then the SLA may be calculated with Equation R4-15.

The effective leakage area method of calculating infiltration for conditioned zones was implemented with the 1992 standards and is still used, but Shielding Class 4 is used for infiltration wind speed reduction, based on the description in the 1997 ASHRAE Handbook of Fundamentals.

Effective leakage areas with ACMs is specified in terms of a default specific leakage area of 4.9 for designs with ducted HVAC systems and an SLA of 3.8 for nonducted HVAC systems. These Specific Leakage Areas (SLA) are the defaults for the *Proposed Design* and the assumed standard value for the *Standard Design*. The

~~specific leakage area is the ratio of the effective leakage area to the floor area of the building in the same units. The value is increased by 10,000 to provide a more manageable metric.~~

Equation R4-15

$$SLA = \left(\frac{ELA}{CFA} \right) \left(\frac{ft^2}{144in^2} \right) (10000) = \left(\frac{ELA}{CFA} \right) 69.444$$

where

ELA = Effective leakage area in square inches

CFA = Conditioned floor area (ft²)

SLA = Specific leakage area (unitless)

Minimum Outside Air.

For both the *Standard Design* and the *Proposed Design*, ACMs shall assume that occupants will open the windows if the house air becomes “too stuffy/stagnant.” When natural ventilation, infiltration, and mechanical ventilation fall below a threshold value of 0.35 air changes per hour (ACH), the occupants are assumed to open the windows at the beginning of the next hour sufficient to provide an indoor air quality increment which is a combination of infiltration and ventilation equal to an additional 0.35 air changes per hour ACH for an eight foot high ceiling. The windows are assumed to remain partially open and provide this to provide a minimum increment of (0.35 air changes per hour) ACH as long as the previous hour’s infiltration and mechanical and natural ventilation rate without this window ventilation for indoor air quality is below the threshold value (see Equations ___ through ___) Calculation of Infiltration and Ventilation.

4.4.2 Calculation of Infiltration and Ventilation

Effective Leakage Area (ELA) Method. The Effective Leakage Area (ELA) method of calculating infiltration for conditioned zones is documented below and in Chapter 265 of the 1997-2001 ASHRAE Handbook of Fundamentals. The ELA for the *Standard Design* and for the default values for the *Proposed Design* (if diagnostic tests are not used), is calculated using the Conditioned Floor Area (CFA) and the Specific Leakage Area (SLA) from Section 4.16 Equation R4-15 above. (The SLA is the ratio of the effective leakage area to the conditioned floor area of the building, in the same units, multiplied by a factor of 10,000 to provide a more manageable metric.) The energy load on the conditioned space from infiltration heat gains or losses are calculated as follows.

Equation R4-16

$$CFM_{infil} = ELA \times \sqrt{A \times \Delta T_2 + B \times V^2}$$

Equation R4-17

$$CFM_{infil+unbal fan} = \sqrt{CFM_{infil}^2 + MECH_{unbal}^2}$$

Equation R4-18

$$CFM_{infil+tot fan} = CFM_{infil+unbal fan} + MECH_{bal}$$

The volumetric airflow (cfm) due to natural ventilation is derived from the natural ventilation cooling for the hour:

Equation R4-19

$$CFM_{natv} = \frac{Q_{natv}}{1.08 \times \Delta T_1}$$

The total ventilation and infiltration (in cfm) including indoor air quality window operation is:

Equation R4-20

$$CFM_{total} = CFM_{natv} + CFM_{infil+totfan} + CFM_{iaq}$$

The value of CFM_{iaq} depends on the sum of CFM_{natv} and $CFM_{infil+totfan}$ from the previous time step:

When

Equation R4-21

$$CFM_{natv} + CFM_{infil+totfan} < \frac{(AFT \times CFA)}{7.5}$$

then

Equation R4-22

$$CFM_{iaq} = \frac{(0.35 \times CFA)}{7.5}$$

otherwise

Equation R4-23

$$CFM_{iaq} = 0.000$$

where

CFA = the total conditioned floor area of the residence

AFT = 0.18 for Climate Zones 2 through 15 inclusive, and;

AFT = 0.25 for Climate Zones 1 and 16.

When the windows are opened they provide an overall ventilation rate equal to 0.35 air changes per hour for a residence of the same floor area but with eight foot high ceilings. CFM_{iaq} simulates the opening of windows to achieve an acceptable indoor air quality by the occupants when ventilation and infiltration from other sources does not provide an adequate quantity of outdoor air to dilute pollutants and refresh the indoor air.

The energy load on the conditioned space from all infiltration and ventilation heat gains or losses is calculated as follows:

Equation R4-24

$$Q_{total} = 1.08 \times CFM_{total} \times \Delta T_1$$

where

Q_{total} = Energy from ventilation and infiltration for current hour (Btu)

CFM_{infil} = Infiltration in cubic feet per minute (cfm)

$CFM_{infil+unbalfan}$ = combined infiltration and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$CFM_{infil+totfan}$ = infiltration plus the balanced and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$MECH_{bal}$ = the balanced mechanical ventilation in cfm. This value is the smaller of the total supply fan cfm and the total exhaust fan cfm.

$MECH_{unbal}$ = the unbalanced mechanical ventilation in cfm. This value is derived from the absolute value of the difference between the total supply fan cfm and the total exhaust fan cfm.

1.08 = conversion factor in (Btu-min)/(hr-ft³-°F)

- ΔT_1 = difference between indoor and outdoor temperature for current hour (°F)
 ΔT_2 = difference between indoor and outdoor temperature for previous hour (°F)
 A = stack coefficient, (cfm²/in⁴/ F)
 B = wind coefficient, (cfm²/in⁴/mph²)
 V = average wind speed for current hour (mph)
 ELA = effective leakage area (in²), measured or calculated using -Equation R4-25. ____
 The stack (A) and wind (B) coefficients to be used are shown in Table R4-8. Table ____7

Table R4-8 – Infiltration Coefficients

Table R4-9 – Infiltration Coefficients

<i>Coefficient</i>	<i>One Floor</i>	<i>Two Floors</i>	<i>Three Floors</i>
A (stack)	0.0156	0.0313	0.0471
B (wind) (Shielding Class 4)	0.0039	0.0051	0.0060

The ELA is calculated from the SLA as follows:

Equation R4-25

$$ELA = CFA \times SLA \times \left(\frac{144 \text{ in}^2}{1 \text{ ft}^2} \right) \times \left(\frac{1}{10,000} \right)$$

where

- CFA = ____ conditioned floor area (ft²)
 SLA = ____ specific leakage area (ft²/ft²)
 ELA = ____ effective leakage area (in²)

Alternatively, ELA and SLA may be determined from blower door measurements:

Equation R4-26

$$ELA = 0.055 \times CFM50_H$$

where

$CFM50_H$ = the measured airflow in cubic feet per minute at 50 pascals for the dwelling with air distribution registers unsealed.

Substituting Equation R4-26 into Equation R4-15 gives the relationship of the measured airflow rate to SLA:

Equation R4-27

$$SLA = 3.819 \times \frac{CFM50_H}{CFA}$$

Reduced Infiltration.

ACM users may take credit for reduced infiltration ~~and (with mechanical ventilation when it is required)~~ for low-rise, single-family dwellings when verified by on-site diagnostic testing. ~~While credit is offered The model for infiltration allows for reduced infiltration, the model entries but also assumes that dwelling occupants will open windows when natural ventilation and infiltration do not provide a minimum of 0.35 ACH. adequate air quality. When infiltration falls below the threshold described in Equation 4.22, ACMs shall assume that occupants open windows in the next hour and add window ventilation to supplement the infiltration and cooling ventilation to achieve an effective air change rate consistent with ASHRAE Standard 62-1989 as described in Equations 4.20 and 4.21.~~

The Effective Leakage Area (ELA) of the dwelling may be reduced and the algorithm will result in less energy use due to infiltration unless windows are opened for ventilation ~~is needed~~. Lower ELAs will result in windows being opened more frequently ~~window ventilation~~ and at some point higher energy use may increase. Air quality ventilation may also be added and if this ventilation plus infiltration and cooling ventilation provides adequate air exchange, window ventilation will no longer occur or will occur very infrequently. The energy use of both ventilation exhaust fans and ventilation supply fans ~~must~~ shall be entered. These ventilation fans are assumed to operate continuously and the energy use of these fans ~~must~~ shall be included as energy use in the energy budget calculated for the dwelling Proposed Design. Except for the set 0.5 SLA reduction credits, ~~Both~~ reduced ELA/SLA and ventilation fans are conditions which require field verification or diagnostic testing ~~by a HERS rater and must~~ shall be reported in the HERS Required Field Verification and Diagnostic Testing listings on the Certificate of Compliance ~~and the Computer Method Summary forms~~.

Controlled Ventilation Crawl Spaces and Sunspaces. Controlled ventilation crawl spaces (CVC) and sunspaces are modeled using the air changes per hour method. Modeling of CVC's and sunspaces are optional capabilities covered in Sections 6.1 and 6.3, respectively Chapter 6. All optional capabilities that are used in the Proposed Design ~~must~~ shall be reported in the Special Features and Modeling Assumptions listings on the Certificate of Compliance ~~and the Computer Method Summary forms~~.

4.5.34.5.2 Natural Ventilation

The natural ventilation model is derived from the ~~1997-2001~~ 2001 ASHRAE Handbook of Fundamentals. The model considers both wind effects and stack effects.

- Wind driven ventilation effects ~~effects~~ includes consideration of wind speed, prevailing direction and local obstructions, such as nearby buildings or hills.
- Stack driven ventilation effects ~~effects~~ includes consideration of the temperature difference between indoor air and outdoor air and the difference in elevation between the air inlet and the outlet.

For compliance purposes, the air outlet is always assumed to be 180 degrees or on the opposite side of the building from the air inlet and the inlet and outlet areas are assumed to be equal. The default inlet area (= outlet area) is five percent of the total window area.

4.5.4 Effective Ventilation Area (EVA)

Both wind and stack driven ventilation depends linearly on the effective ventilation area (EVA). The EVA is a function of the area of the air inlet and the area of the air outlet. For compliance purposes, the default area of air inlet and outlet are both equal to five per cent ~~(half of the total default standard window opening area)~~ of the total window area, i.e., total ventilation area is 10% of the window area. For compliance purposes a different window opening areas may be determined from the areas of different window opening types - fixed, sliders, and hinged windows. ~~For research (as opposed to compliance) purposes, inputs for ACMs may enter separate values for inlet and outlet areas.~~ For compliance purposes, the air inlet and the air outlet are each equal to one-half of the Free Ventilation Area ~~described in Section 4.13 below~~.

When the inlet area and outlet area are equal, the EVA is the same, i.e. equal to the inlet area or the outlet area. Hence for compliance purposes the EVA is equal to one-half of the Free Ventilation Area.

4.5.5 Stack Driven Ventilation

Stack driven ventilation results when there is an elevation difference between the inlet and the outlet, and when there is a temperature difference between indoor and outdoor conditions. See Equation R4-28.

Equation R4-28

$$CFM_S = 9.4 \times EVA \times EFF_S \times \sqrt{H \times \Delta T}$$

~~Where:~~

CFM_S = Airflow due to stack effects, cfm.

9.4 = Constant from ASHRAE.

EVA = Effective ventilation area as discussed above, ft².

EFF_S = Stack effectiveness.

H = Center-to-center height difference between the air inlet and outlet.

ΔT = Indoor to outdoor temperature difference, °F.

For compliance purposes the stack effectiveness shall be set at 1.0. The ACM user shall not be permitted to alter this value.

~~H = ——— is the ventilation height difference. See Section 4.14 for details.~~

4.5.6 Wind Driven Ventilation

The general equation for wind driven ventilation is shown below. This equation works in either a direction dependent implementation or a direction independent implementation, as explained later in the text.

Equation R4-29

$$CFM_W = EVA \times 88 \times MPH \times WF \times EFF_O \times EFF_d$$

~~Where:~~

CFM_W = Ventilation due to wind, cfm.

EVA = Effective vent area as discussed above, ft².

88 = A constant that converts wind speed in mph to wind speed in feet per minute.

MPH = Wind speed from the weather tape, mph.

WF = A multiplier that reduces local wind speed due to obstructions such as adjacent buildings. This input is fixed at 0.25 for compliance calculations.

EFF_O = Effectiveness of opening used to adjust for the location of the opening in the building, e.g. crawl space vents. This accounts for insect screens and/or other devices that may reduce the effectiveness of the ventilation opening. This input is also used to account for the location of ventilation area, e.g. the exceptional method for two-zone crawl space modeling provides for an alternative input for EFF_O . This input is fixed at 1.0 for compliance calculations other than crawlspace modeling.

EFF_d = Effectiveness that is related to the direction of the wind relative to the inlet surface for each hour. ASHRAE recommends that the effectiveness of the opening, EFF_d , be set to between 0.50 and 0.60 when the wind direction is perpendicular or normal to the inlet and outlet. A value of 0.25 to 0.35 is recommended for diagonal winds. When the wind direction is parallel to the surface of the inlet and outlet, EFF_d should be zero.

~~WF is the wind correction factor; this input is fixed at 0.25 for compliance calculations.~~

~~The effectiveness of the ventilation opening, EFF_o , is used to account for insect screens and/or other devices that may reduce the effectiveness of the ventilation opening. This input is also used to account for the location of ventilation area, e.g. the exceptional method for two zone crawl space modeling provides for an alternative input for EFF_o . This input is fixed at 1.0 for compliance calculations other than crawlspace modeling.~~

~~ASHRAE recommends that the effectiveness of the opening, EFF_o , be set to between 0.50 and 0.60 when the wind direction is perpendicular or normal to the inlet and outlet. A value of 0.25 to 0.35 is recommended for diagonal winds. When the wind direction is parallel to the surface of the inlet and outlet, EFF_o should be zero.~~

For compliance calculations, the orientation of the inlet and outlet is not considered. ACMs shall assume that the wind angle of incidence at 45 degrees on all windows and only the wind speed dependence is maintained. In this case, the product of EFF_o and EFF_d is equal to 0.28 regardless of the direction of the wind.

4.5.7 Combined Wind and Stack Effects

Stack effects and wind effects are calculated separately and added by quadrature, as shown below. This algorithm always adds the absolute value of the forces; that is, wind ventilation never cancels stack ventilation even though in reality this can happen.

Equation R4-30

$$CFM_t = \sqrt{CFM_w^2 + CFM_s^2}$$

~~Where:~~

CFM_t = Total ventilation rate from both stack and wind effects, cfm.

CFM_w = Ventilation rate from wind effects, cfm.

CFM_s = Ventilation rate from stack effects, cfm.

4.5.8 Determination of Natural Ventilation for Cooling

The value of CFM_t described in Equation R4-30 ~~Equation 4.10~~ above gives the maximum potential ventilation when the windows are open. Natural ventilation is available during cooling mode when there is venting shown in Table R4-1. The amount of natural ventilation used by ACMs for natural cooling is the ~~lessor~~ lesser of this maximum potential amount available and the amount needed to drive the interior zone temperature down to the natural cooling setpoint temperature when natural cooling is needed and available. When natural cooling is not needed or is unavailable no natural ventilation is used. ACMs shall assume that natural cooling is needed when the building is in "cooling mode" and when the outside temperature is below the estimated zone temperature and the estimated zone temperature is above the natural cooling setpoint temperature. Only the amount of ventilation required to reduce the zone temperature down to the natural ventilation setpoint temperature is used and the natural ventilation setpoint temperature ~~must~~ shall be constrained by the ACM to be greater than the heating setpoint temperature.

Free Ventilation Area

~~Free ventilation area is the adjusted area taking into account bug screens, window framing and dividers, and other factors.~~

Standard Design: ~~The Standard Design value for free ventilation area is 10% of the fenestration area (rough frame opening). This value is also used for the window Opening Type Slider. The approved ACM compliance manual shall note that fenestration opening type Slider also may be selected by the user or automatically used by the ACM as a default or "Standard" opening type. This is based upon the assumption that approximately 40% of the rough frame opening is available for ventilation. Half of this area is considered an air inlet and half~~

an air outlet. This value shall always be used for the *Standard Design* run. It is also the default for the *Proposed Design* run.

Proposed Design: Other values may be used in the *Proposed Design* run only when special windows are installed, high mass is installed, and the "high mass" input option is selected [or the ACM determines that *Proposed Design's* thermal mass exceeds the mass threshold]. The free ventilation area is assumed to be 20% of the fenestration area for hinged type windows such as casements, awnings, hoppers, patio doors and French doors that are capable of a maximum ventilation area of approximately 80% of the rough frame opening. If the ACM user increases the ventilation area for hinged type windows, the ACM must also consider the possible effect of fixed glazing in the building which has no free ventilation area (window opening type *Fixed*). The ACM user may account for additional free ventilation area by entering the total area for sliding windows, the total area for hinged windows, and the total area of fixed windows in the "high mass" menu of the ACM. The ACM must verify that the total area entered for these three types is the same as the total area of windows calculated elsewhere or the ACM may determine the area of fixed windows by subtracting the slider window area and the hinged window area from the total window area if it is less than the total window and skylight area. If the total window and skylight area is less than the area specified for sliding windows and hinged windows the ACM must reduce the area of hinged windows by the difference. The total ventilation area is calculated from the areas of the three possible fenestration opening types, as shown below:

$$\text{Equation 4.32} \quad \text{Vent Area} = (\text{Area Slider} \times 0.1) + (\text{Area Hinged} \times 0.2) + (\text{Area Fixed} \times 0.0)$$

The ACM's ability to accept a customized ventilation area is an optional capability. When this optional capability is used, the fact that the user entered a customized free ventilation area and the total areas of each of these three fenestration opening types must be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R and C-2R. Note that the maximum free ventilation area that may be modeled by any ACM for compliance purposes is 20% of the total area of windows and skylights assuming that all windows and skylights are hinged.

4.5.10 Ventilation Height Difference

Standard Design: The *Standard Design* modeling assumptions for the elevation difference between the inlet and the outlet is two feet for one-story buildings and eight feet for two or more stories.

Proposed Design: For the *Proposed Design* run, the assumption is the same as the *Standard Design* except that greater height differences may be used with special ventilation features such as high, operable clerestory windows. In this case the height difference is the height between the average center height of the lower operable windows and the average center height of the upper operable windows. Such features must be fully documented on the building plans and noted on the ACM standard reports in the *Special Features and Modeling Assumptions* listings as a condition that requires special verification.

4.5.11 Wind Speed and Direction

Standard Design & Proposed Design: Wind speed affects the infiltration rate and the natural ventilation rate. The infiltration and ventilation rate in the reference method accounts for local site obstructions. For infiltration in the reference method this is done by using Shielding Class 4 coefficients in the Sherman-Grimsrud equation (Section 4.17.1, Equation 4.17 see 2001 ASHRAE Fundamentals, Chapter 26) to determine the stack and wind driven infiltration and ventilation. This Shielding Class determination was made on the basis of the description of the Shielding Classes given in the 1997-2001 ASHRAE Handbook of Fundamentals, Table 7, Page 25.22. For Shielding Class 4 the description, which reads as follows:

Heavy shielding; obstructions around most of the perimeter, buildings or trees within 30 feet in most directions; typical suburban shielding.

For natural ventilation in the reference method, CALRES, adjusts the wind speed used in calculations is adjusted for differences between the measured wind speed height and the inlet opening height and local obstructions by using a wind factor (through a WF in Equation 4.9) of 0.25. See Equation R4-29.

4.6 Heating Systems

ACMs shall use the following inputs and algorithms to calculate heating energy use.

$$\text{Equation R4-31} \quad \text{NetHLoad}_{\text{hr}} = \frac{\text{HLoad}_{\text{hr}} \times \text{HDEM}_{\text{hr}}}{\eta_{\text{seasonal,dist}}}$$

where

$\text{NetHLoad}_{\text{hr}}$ = The net heating load that the heating equipment sees. This accounts for air distribution duct losses. If there are no air distribution ducts then $\text{NetHLoad} = \text{HLoad}_{\text{hr}}$.

HLoad_{hr} = Space heating load for the hour from the ACM simulation, Btu.

$\eta_{\text{seasonal,dist}}$ = Seasonal distribution system efficiency for the heating season from Equation R4-55.

HDEM_{hr} = Heating duct efficiency multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 (no hourly adjustment) is used unless the supply ducts are located in the attic. .

4.6.1 Furnaces and Boilers

Once the net heating load is known, heating energy for gas fired equipment is calculated each hour by dividing the net heating load for that hour by the AFUE. There are no hourly adjustments for part load conditions or temperature dependencies.

$$\text{Equation R4-32} \quad \text{FurnFuel}_{\text{hr}} = \frac{\text{NetHLoad}_{\text{hr}}}{\text{AFUE}_{\text{eff}}}$$

where

AFUE_{eff} = Annual fuel utilization efficiency. This is a constant for the year.

$\text{NetLoad}_{\text{hr}}$ = The hourly load calculated from Equation R4-31 and using algorithms similar to those described in this chapter.

4.6.2 Heat pump and Electric Furnace

The reference ACM has a heat pump model which takes account of outdoor temperature. The model uses the following inputs.

HSPF = Rated Heating Seasonal Performance Factor

EIR47 = Defaults to $1/(0.4 \times \text{HSPF})$

Cap47 = Rated compressor heating capacity at 47 F. Defaults to rated cooling capacity.

If the heat pump compressor is not large enough to meet the load in the hour, the ACM assumes there is sufficient backup resistance heat. In the case of an electric furnace, the load shall be met entirely by resistance heat. For heat pumps, the ACM shall calculate the hourly heating electricity consumption in kWh using the DOE2.1E heat pump algorithm.

For equipment without an HSPF rating, the HSPF may be calculated as:

$$\text{Equation R4-33} \quad \text{HSPF} = (3.2 \times \text{COP}) - 2.4$$

4.64.6.3 Heating Equipment and Air Distribution Fans

The efficiency of fossil fuel fired heating equipment (furnaces, boilers, etc.) is rated as an Annual Fuel Utilization Efficiency (AFUE). The test method for calculating AFUE ignores electric energy used by air distribution fans and the contribution of the fan motor input to the heating output. The fan energy is calculated at the rate of 0.005 watt-hours per Btu of heat delivered by the equipment.

With TDV, electric energy shall be calculated separately from gas energy. For forced-air heating systems, ACMs shall calculate fan energy at the rate of 0.005 watt-hours per Btu of heat delivered by the equipment. The vast majority of residential furnaces have the fan motor in the air stream so the heat generated by the motor contributes to heating the house. This effect may be considered in calculating the TDV-energy for heating.

The heating source energy may be calculated using an effective AFUE which accounts for both the heat contribution of the fan and the source energy used by the fan. The effective AFUE is a similar number to the seasonal efficiency used in pre 1992 ACMs.

$$\text{Equation 4.33} \quad \text{AFUE}_{\text{eff}} = \frac{1 + 0.005(3.413)}{\frac{1}{\text{AFUE}} + 0.005(10.239)}$$

- The effective AFUE is used for all furnaces and boilers that use ducted distribution systems.

4.4.5 Commission Equivalent Efficiencies

The approved ACM compliance supplement must include the following conversion and substitution:

For equipment without an HSPF rating, the HSPF may be calculated as:

$$\text{Equation 4.34} \quad \text{HSPF} = (3.2 \times \text{COP}) - 2.4$$

The EER may be used in lieu of the SEER for equipment not required to be tested for an SEER rating.

4.5 Duct Efficiency

The Commission has approved algorithms and procedures for determining duct and HVAC distribution efficiency. Details are presented in Appendix RF.

There are two calculation procedures to determine seasonal air distribution efficiency using either 1) default input assumptions or 2) diagnostic measurement values. Air distribution efficiencies for heating and cooling shall be calculated separately. The ACM shall require the user to choose values for the following parameters to calculate seasonal duct efficiencies as shown below. The ACM shall use the defaults shown in [brackets] for the *Standard Design*:

1. Location of the duct system [ducts in the attic]
2. Insulation level of ducts [R 4.2]
3. The surface area of ducts or separate supply and return surface areas [27% of conditioned floor area (CFA) for supply duct surface area; 5% CFA for return duct surface area in single story dwellings and 10% CFA for return duct surface area in dwellings with two or more stories] or the installer measured and HERS rater verified reduced surface area of supply ducts in conjunction with ACCA Manual D design and installer measured and HERS rater verified fan flow consistent with the ACCA Manual D design as specified in 5. below. 7.68

4. ~~The leakage level of the duct system [6% of fan flow]. Two values are possible for the proposed design: 6% of fan flow if installer measured and HERS rater verified at no more than 6% of fan flow, otherwise 22% of fan flow shall be used.~~
5. ~~ACCA manual D design, duct layout and system fan flow [No]. This requires that engineering calculations and a duct layout have been prepared as part of the building plans and that system fan flow specified in those calculations be installer measured and HERS rater verified.~~
6. ~~Designation for systems with less than 12 feet of duct outside conditioned space [No].~~
7. ~~Attic duct efficiency with radiant barrier in accordance with Package D requirements [Yes in climate zones where required by Package D, otherwise No].~~

~~When any duct efficiency credit is claimed beyond the default assumptions that requires diagnostic testing or verification by a HERS rater or the local enforcement agency, i.e. when non default values (except HVAC equipment capacities) are used to determine duct efficiency, the leaks in the air distribution system connections shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands and this requirement must be specified in the *Special Features and Modeling Assumptions* listings and the *HERS Required Verification* listings on the CF-1R and the C-2R.~~

The ACM shall automatically use the following values from the description of the *Proposed Design* when calculating the distribution system efficiency:

- Number of stories
- Building Conditioned Floor Area
- Building Volume
- Floor Type
- Presence of attic radiant barrier or cool roof
- Presence of insulation between floor above crawlspace or unconditioned basement, and on or within crawlspace or basement walls adjacent to outside conditions or the ground below
- Outdoor summer and winter design temperatures for each climate zone

~~When more than one HVAC system serves the building or dwelling, the HVAC distribution efficiency is determined for each system and an conditioned floor area weighted average seasonal efficiency is determined based on the inputs for each of the systems.~~

~~When an existing HVAC system is extended to serve an addition, the default assumptions for duct and HVAC distribution efficiency must be used for both the *Proposed Design* and the *Standard Design*. However, when a new, high efficiency HVAC distribution system is used to serve the addition or the addition and the existing building, that system may be modeled to receive energy credit subject to diagnostic testing and verification of proper installation by a HERS rater.~~

4.6 4.22 Slab Heat Loss (F2 Factor)

See Section 4.7.1.

4.7 Air Conditioning Systems

Air conditioning systems shall be sized, installed, tested and modeled according to the provisions of this section.

4.7.1 Cooling System Energy

The reference ACM calculates the hourly cooling electricity consumption in kWh using Equation R4-34. In this equation, the energy for the air handler fan and the electric compressor or parasitic power for the outdoor unit of a gas ~~fired~~-absorption air conditioner are combined. The ACM calculates the hourly cooling gas consumption in therms using Equation 4-35 ~~fan and the compressor are combined.~~

$$\text{Equation R4-34} \quad AC_{kWh} = \frac{Fan_{Wh} + Comp_{Wh} + PPC_{Wh}}{1,000}$$

$$\text{Equation 4-35} \quad AC_{therms} = \frac{Absorption_{Btu}}{100,000}$$

where

AC_{kWh} = Air conditioner kWh of electricity consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

Fan_{Wh} = Fan watt-hours for a particular hour of the simulation. See Equation R4-48.

$Comp_{Wh}$ = Compressor watt-hours for a particular hour of the simulation. This is calculated using Equation R4-36.

PPC_{Wh} = Parasitic Power watt-hours for gas ~~fired~~ absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R4- ~~44~~~~X2~~.

AC_{therms} = Air conditioner therms of gas consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

$Absorption_{Btu}$ = Gas consumption in Btu for absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R4-~~43~~~~X1~~.

Electric Compressor Systems

The reference method calculates the energy for electrically driven compressors using the algorithms described in this section.

Compressor watt-hours for a particular hour of the simulation shall be calculated using Equation R4-36.

$$\text{Equation R4-36} \quad Comp_{Wh} = \frac{CLoad_{hr} \times CDEM_{hr}}{\eta_{seasonal,dist} \times CE_t} + \frac{Fan_{Wh} \times 3.413}{CE_t}$$

where

$CLoad_{hr}$ = Space sensible cooling load for the hour from the ACM simulation (Btu).

$CDEM_{hr}$ = Cooling Duct Efficiency Multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 is used unless the supply ducts are located in the attic.

$\eta_{seasonal,dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54
 $\eta_{dist,seasonal} = 0.98 DE_{seasonal} \times F_{recov}$

CE_t = Sensible energy efficiency at a particular outdoor dry bulb temperature. This is calculated using Equation R4-37 below.

Fan_{Wh} = Fan watts this hour. This is calculated using Equation R4-48.

Equation R4-37 _____ $CE_t = EER_t \times (0.88 + 0.00156 \times (DB_t - 95))$

where

$DB_t =$ Outdoor dry bulb temperature taken from the CEC weather file.

$EER_t =$ Energy efficiency ratio at a particular dry bulb temperature. EER_t is calculated using Equation R4-38 below.

Equation R4-38

When

$DB_t < 82^\circ\text{F}$ $EER_t = SEER_{nf}$

$82 \leq DB_t < 95$ $EER_t = SEER_{nf} + ((DB_t - 82) \times (EER_{nf} - SEER_{nf}) / 13)$

$DB_t \geq 95$ $EER_t = EER_{nf} - (DB_t - 95) \times 0.12$

where

$SEER_{nf} =$ Seasonal energy efficiency ratio without distribution fan consumption ("nf" = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R4-39.

$EER_{nf} =$ Energy efficiency ratio at ARI conditions without distribution fan consumption ("nf" = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R4-40.

Equation R4-39 _____ $SEER_{nf} = (1.0452 \times SEER + 0.0115 \times SEER^2 + 0.000251 \times SEER^3) \times F_{txv} \times F_{air} \times F_{size}$

Equation R4-40 _____ $EER_{nf} = (1.0452 \times EER + 0.0115 \times EER^2 + 0.000251 \times EER^3) \times F_{txv} \times F_{air} \times F_{size}$

where

$SEER =$ Seasonal energy efficiency ratio for the air conditioner. The EER shall be used in lieu of the SEER for equipment not required to be tested for a SEER rating.

$EER =$ Energy efficiency ratio at ARI test conditions, if not input, then values are taken from Equation R4-41.

$F_{txv} =$ The refrigerant charge factor, default = 0.9. For systems with a verified TXV (ACM RI-2005) or verified refrigerant charge (ACM RD-2005), the factor shall be 0.96.

$F_{air} =$ The system airflow factor, default = .925. For systems with airflow verified according to 4.7.4, F_{air} shall be 1.00.

$F_{size} =$ Compressor sizing factor, default = 0.95. For systems sized according to the Maximum Cooling Capacity for ACM Credit (see Section 4.7.2), the factor shall be 1.0.

Equation R4-41

When

$SEER < 11.5$ $EER = 10 - (11.5 - SEER) \times 0.83$

$SEER \geq 11.5$ $EER = 10$

Gas Absorption Systems

To determine the electric and gas energy use of gas ~~fire~~-absorption air conditioning systems the algorithms described in this section should be used.

$$\text{Equation R4-42} \quad \text{Absorption}_{\text{Btu}} = \frac{\text{CLoad}_{\text{hr}} \times \text{CDEM}_{\text{hr}}}{\eta_{\text{seasonal,dist}} \times \text{AE}_t} + \frac{\text{Fan}_{\text{wh}} \times 3.413}{\text{AE}_t}$$

$$\text{Equation R4-43} \quad \text{PPC}_{\text{wh}} = \frac{\text{CLoad}_{\text{hr}} \times \text{CDEM}_{\text{hr}}}{\eta_{\text{seasonal,dist}} \times \text{PE}_t}$$

where:

$\text{CLoad}_{\text{hr}} =$ Space sensible cooling load for the hour from the ACM simulation (Btu).

$\text{CDEM}_{\text{hr}} =$ Cooling Duct Efficiency Multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 is used unless the supply ducts are located in the attic.

$\eta_{\text{seasonal,dist}} =$ Seasonal distribution system efficiency for the cooling season from Equation R4-54.

$\text{AE}_t =$ Sensible energy efficiency of the gas ~~fire~~-absorption ~~air~~ system at a particular outdoor dry bulb temperature. This is calculated Equation R4-44 ~~52~~ using below.

$\text{PE}_t =$ Sensible energy efficiency of the parasitic power at a particular outdoor dry bulb temperature. This is calculated using Equation R4-45 ~~46~~ below.

$\text{Fan}_{\text{wh}} =$ Fan watts this hour. This is calculated using Equation R4-48 ~~45~~.

$$\text{Equation R4-44} \quad \text{AE}_t = \text{COP}_t \times (0.88 + 0.00156 \times (\text{DB}_t - 95))$$

$$\text{Equation R4-45} \quad \text{PE}_t = \text{PEER}_t \times (0.88 + 0.00156 \times (\text{DB}_t - 95))$$

where

$\text{DB}_t =$ Outdoor dry bulb temperature taken from the CEC weather file.

$\text{COP}_t =$ COP (coefficient of performance for the gas consumption) of the gas absorption ~~air~~ system at a particular dry bulb temperature calculated using Equation R4-46 ~~54~~.

$\text{PEER}_t =$ PEER (parasitic electricity energy efficiency for the ~~outdoor~~ gas absorption ~~air~~ system) at a particular ~~outdoor~~ dry bulb temperature calculated using Equation R4-48 ~~46~~.

Equation R4-46

$\text{DB}_t < 83^\circ\text{F}$

$\text{COP}_t = \text{COP}_{82}$

$83 < DB_i < 95$	$COP_i = COP_{82} + ((DB_i - 82) * (COP_{95} - COP_{82}) / 13)$
$DB_i > 94$	$COP_i = COP_{95} - (DB_i - 95) * 0.00586$

Equation R4-47

$DB_i < 83\text{ }^{\circ}\text{F}$	$PEER_i = PEER_{82}$
$83 < DB_i < 95$	$PEER_i = PEER_{82} + ((DB_i - 82) * (PEER_{95} - PEER_{82}) / 13)$
$DB_i > 94$	$PEER_i = PEER_{95} - (DB_i - 95) * 0.00689$

where

CAP95= Rated capacity of the gas fired absorption ~~ber~~ system, Btuh, input by the compliance userCOP95 = Rated COP of the gas fired absorption ~~ber~~ system, input by compliance userPPC = Parasitic electric energy ~~ratio~~ at rated conditions, W, input by compliance user $COP_{82} = COP_{95} * 1.056$ $PEER_{95} = CAP_{95} / PPC, \text{ Btu BTU} / \text{Wh}$ $PEER_{82} = PEER_{95} * 1.056$ **Fan Energy for Cooling**

While in a cooling mode, the fan energy associated with the air conditioner is calculated separately from the compressor energy according to Equation R4-48. Calculations are performed hourly.

$$\text{Equation R4-48} \quad \text{Fan}_{wh} = \frac{\text{FanW} / \text{Btu} \times \text{CLoad}_{hr} \times \text{CDEM}_{hr}}{\eta_{\text{seasonal, dist}}}$$

where

FanW/Btu = Fan watts per Btu of rated cooling capacity. This defaults to 0.015 W/Btu. The default value shall be used for the Standard design. Alternate FanW/Btu may be used in ACM calculations for the Proposed design if the actual installed fan watts are less than or equal to the simulation value based on measurements certified by the installer and verified by a rater using the procedure in ACM REF-2005.

$\eta_{\text{seasonal, dist}}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54.

4.7.2 Compressor Sizing

The Design Cooling Capacity shall be calculated using the procedure in ACM RF-2005. The Maximum Cooling Capacity for ACM Credit shall be calculated using the procedure in ACM RF-2005. For ACM energy calculations all loads are assumed to be met in the hour they occur regardless of the compressor size.

Correctly sized systems installed so they operate at full capacity are desirable because oversized cooling systems have been shown to result in larger peak electrical demands. Systems which have the combination of verified adequate airflow, sealed and tested new duct systems, and proper charge (or alternatively a TXV) and also meet the requirements for Maximum Cooling Capacity for ACM Credit may take credit in ACM calculations by setting the Fsize factor (see Equation R4-39 and Equation R4-40) to 0.95. For all other systems the Fsize factor shall be set to 1.0.

4.7.3 Cooling System Refrigerant Charge

Proper refrigerant charge is necessary for electrically driven compressor air conditioning systems to operate at full capacity and efficiency. The presence of a thermostatic expansion valve (TXV) mitigates the impact of charge problems. Field measurements indicate that typical California air conditioning systems are installed without proper charge, and for ACM energy calculations, the F_{txv} factor is set to 0.90 to account for the impact of this condition. If the system without a TXV is properly charged or a TXV is installed, certified and verified according to the procedures of ACM RD-2005 the F_{txv} factor may be set to 0.96 for ACM energy calculations. See Equation R4-39 and Equation R4-40. Credit for refrigerant charge is not available for package systems.

4.7.4 Air Handler Airflow

The efficiency of an air conditioning system is affected by airflow across the evaporator coil. Cooling system airflow is specified in cubic feet per minute per ton (cfm/ton) where one ton of capacity is 12,000 Btu/hour at ARI rated conditions. Cooling airflow is the flow achieved under normal air conditioning operation with the cooling coil wet from condensation.

Adequate Airflow Verification

Verifying adequate airflow is required to allow air conditioning systems to operate at their full efficiency and capacity. Credit may be taken for adequate airflow in ACM calculations by setting the F_{air} factor (see Equation R4-39 and Equation R4-40) to 1.0, but airflow shall be tested, certified and verified using the procedures of ACM RE-2005. When an adequate airflow credit is claimed, the duct design, layout, and calculations shall also be submitted to the local enforcement agency and to a certified HERS rater. Without airflow tests, no credit is allowed for ACM energy calculations and the F_{air} multiplier shall be set to 0.925.

The installer shall measure and certify the airflow. The certified HERS rater shall verify the existence of the duct design layout and calculations, verify that the field installation is consistent with this design, and diagnostically test and verify the airflow rate.

Sufficient Flow for Valid Standard Refrigerant Charge Test

Sufficient airflow is also required to ensure that the refrigerant charge procedure in ACM RD-2005 will produce valid results. Verifying sufficient airflow is a prerequisite for the refrigerant charge test. Either the flow measurement procedure or the temperature split test of ACM RD-2005 may be used to demonstrate Sufficient Airflow.

Air Handler Fan Flow

Table R4-9 shows the criteria used for calculations and measurement of airflow for cooling systems. If a flow test is done using the fan only switch on the air handler, the coil will be dry allowing higher airflow, and the Dry Coil criterion shall be used.

Table R4-9 – Airflow Criteria

Note: All airflows are for the fan set at the speed used for air conditioning.

<u>Test and Condition</u>	<u>Cooling airflow (Wet Coil)</u>	<u>Test Flow if Dry Coil</u>
<u>Default Cooling Airflow</u>	<u>300 cfm/ton</u>	<u>N/A</u>
<u>Flow needed for a valid refrigerant charge test</u>	<u>350 cfm/ton (See Note 1)</u>	<u>400 cfm/ton</u>
<u>Adequate Airflow</u>	<u>400 cfm/ton</u>	<u>450 cfm/ton</u>
<u>Note 1. In lieu of airflow measurements, the system can pass the temperature split test documented in ACM RD-2005.</u>		

4.8 Duct Efficiency

The procedures in this section shall be used to calculate the efficiency of duct systems. For the purposes of duct efficiency calculations, the supply duct begins at the exit from the furnace or air handler cabinet.

4.8.1 Building Information and Defaults

The ACM shall use values for the parameters in Table R4-10 to calculate duct efficiencies. - Standard design values and proposed design defaults are also shown. Proposed designs may claim credit for other values using the procedures in the following sections.

Table R4-10 – Duct Efficiency Input Parameters and Defaults

Parameter	Standard Design Value	Proposed Design Default
1. <u>Duct Location</u>	<u>Ducts in the attic</u>	<u>Ducts in the attic</u>
2. <u>Insulation level of ducts</u>	<u>Package D requirement</u>	<u>Mandatory Minimum Requirement</u>
3. <u>The surface area of ducts</u>	<u>27% of conditioned floor area (CFA) for supply duct surface area; 5% CFA for return duct surface area in single story dwellings and 10% CFA for return duct surface area in dwellings with two or more stories.</u>	
4. <u>The leakage level</u>	<u>Sealed and tested.</u>	<u>Untested</u>
5. <u>Fan flow</u>	<u>Default Cooling Airflow (Table R4-9)</u>	
6. <u>Attic radiant barrier.</u>	<u>Yes in climate zones where required by Package D, otherwise No</u>	<u>No radiant barrier</u>

-When more than one HVAC system serves the building or dwelling, the HVAC distribution efficiency is determined for each system and a conditioned floor area-weighted average seasonal efficiency is determined based on the inputs for each of the systems.

See Section 3.8 for information on existing HVAC systems that are extended to serve an addition.

Diagnostic inputs may be used for the calculation of improved duct efficiency in the *Proposed Design*. The diagnostics include observation of various duct characteristics and measurement of duct leakage as described in the following sections. These observations and measurements replace those assumed as default values.

4.8.2 Duct Location

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Note that the area of supply ducts located in conditioned space shall be ignored in calculating conduction losses but supply duct leakage is not affected by supply duct location.

Return Duct Location

If return ducts are located entirely in the basement, the calculation shall assume basement conditions for the return duct efficiency calculation. Otherwise, the return duct shall be entirely located in the attic for the purposes of conduction and leakage calculations. Return duct surface area is not a compliance variable.

Default Supply Duct Location

Default supply duct locations shall be as shown in Table R4-11. The supply duct surface area for crawl space and basement applies only to buildings or zones with all supply ducts installed in the crawl space or basement. If the supply duct is installed in locations other than crawl space or basement, the default supply duct location shall be "Other." For houses with 2 or more stories 35% of the default duct area may be assumed to be in conditioned space as shown in Table R4-11. The surface area of supply ducts located in conditioned space shall be ignored in calculating conduction losses. The *Standard Design* building is assumed to have the same number of stories as the *Proposed Design* for purposes of determining the duct efficiency.

Table R4-11 – Location of Default Supply Duct Area

Supply duct location	Location of Default Supply Duct Surface Area	
	One story	Two or more story
All in Crawl Space	100% crawl space	65% crawl space 35% conditioned space
All in Basement	100% Basement	65% basement 35% conditioned space
Other	100% attic	65% attic 35% conditioned space

Diagnostic Supply Duct Location

Supply duct location and areas other than the defaults shown in Table R4-11 may be used following the procedures of 4.8.5.

4.8.3 Duct Surface Area

The supply-side and return-side duct surface areas shall be treated separately in distribution efficiency calculations. The duct surface area shall be determined using the following methods.

Return Duct Surface Area

Return duct surface area is not a compliance variable and shall be calculated using Equation R4-49.

$$\text{Equation R4-49} \quad A_{r,out} = K_r \times A_{floor}$$

Where K_r (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.

Default Supply Duct Surface Area

The standard design and default supply duct surface area shall be calculated using Equation R4-50.

$$\text{Equation R4-50} \quad A_{S,out} = 0.27 \times A_{floor} \times K_S$$

Where K_S (supply duct surface area coefficient) shall be 1 for one story building and 0.65 for two or more stories.

Supply Duct Surface Area for Less Than 12 feet of Duct Outside Conditioned Space

For proposed design HVAC systems with air handlers located outside the conditioned space but with less than 12 lineal feet of duct located outside the conditioned space including air handler and plenum, the supply duct surface area outside the conditioned space shall be calculated using Equation R4-51.

$$\text{Equation R4-51} \quad A_{s,out} = 0.027 \times A_{floor}$$

Diagnostic Duct Surface Area

Proposed designs may claim credit for reduced surface area using the procedures in 4.8.5.

4.8.4 Duct System Insulation

General

An air film resistance of 0.7 (h-ft²-°F/Btu) shall be added by the ACM to the insulation R-value to account for external and internal film resistance. For the purposes of conduction calculations in both the Standard and Proposed designs, 85% of the supply and return duct surface shall be assumed to be duct material at its specified R-value and 15% shall be assumed to be air handler, plenum, connectors and other components at the mandatory minimum R-value.

Standard Design Duct Insulation R-value

Package D required duct insulation R-values shall be used in the Standard design.

Proposed Design Duct Insulation R-value

The default duct wall thermal resistance shall be the mandatory requirement. Higher insulation levels may be used in the proposed design if all the ducts outside conditioned space are insulated to this value or greater. Credit for systems with mixed insulation levels or ducts buried in the attic require the diagnostic procedure in 4.8.5.

4.8.5 Diagnostic Supply Duct Location, Surface Area and R-factor

Credit is available for supply duct systems entirely in conditioned space, with reduced surface area in unconditioned spaces and combinations of higher performance insulation. In order to claim this credit the detailed duct system design shall be documented on the plans, and the installation shall be certified by the installer and verified by a HERS rater. The size, R-value, and location of each duct segment in an unconditioned space and if buried in attic insulation, the information described below shall be shown in the design and entered into the ACM. The ACM shall calculate the area and effective R-value of the duct system in each location using the procedures specified below.

Surface Area and Location

The surface area of each supply duct system segment shall be calculated based on its inside dimensions and length. The total supply surface area in each unconditioned space location (attic, attic with radiant barrier, crawl space, basement, other) shall be the sum of the area of all duct segments in that location. The ACM shall assign duct segments located in "other" locations to the attic location for purposes of calculation. The surface area of supply ducts completely inside conditioned space need not be input in an ACM and is not included in the calculation of duct system efficiency. The area of ducts in floor cavities or vertical chases that are surrounded by conditioned space and separated from unconditioned space with draft stops are also not included.

Effective R-value

The effective R-value of a supply or return duct system constructed entirely of materials of one rated R-value shall be the rated R-value plus the film coefficient. If materials of more than one R-value are used, the area weighted effective R-value shall be calculated by the ACM using Equation R4-52 and including each segment of the duct system which has a different R-value.

$$\text{Equation R4-52} \quad R_{\text{eff}} = \frac{(A_1 + A_2 + \dots + A_N)}{\left[\frac{A_1}{R_1} + \frac{A_2}{R_2} + \dots + \frac{A_N}{R_N} \right]}$$

where

R_{eff} = Area weighted effective R-value of duct system for use in calculating duct efficiency, (h-ft²-°F/Btu)

A_N = Area of duct segment n, square feet.

R_n = R-value of duct segment n including film resistance, (duct insulation rated R + 0.7), (h-ft²-°F/Btu)

Buried Attic Ducts

Ducts partly or completely buried in blown attic insulation in dwelling units meeting the requirements for High Insulation Quality (ACM RH) and Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems (ACM RC) may take credit for increased effective duct insulation using the following procedure. The duct design shall identify the segments of the duct that meet the requirements for being buried, and these shall be separately input into the ACM. Ducts to be buried shall have a minimum of R-4.2 duct insulation prior to being buried. The ACM shall calculate the correct R-value based on the specified attic insulation R-value, insulation type, and duct size for ducts installed on the ceiling, and whether the installation meets the requirements for deeply buried ducts for duct segments buried in lowered areas of ceiling. Correct installation of the duct system and attic insulation shall be certified by the installer and verified by a certified HERS rater (including that the requirements of ACM RH and ACM RC are met).

Buried Ducts on the Ceiling

The portions of duct runs directly on or within 3.5 inches of the ceiling gypsum board and surrounded with blown attic insulation of R-30 or greater in houses meeting the criteria for High Insulation Quality (ACM RQ) may take credit for increased effective duct insulation as shown in Table R4-12. Credit shall be allowed for buried ducts on the ceiling only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above. ~~Ducts to be buried shall have R-4.2 insulation installed prior to burial.~~

Deeply Buried Ducts

Duct segments deeply buried in lowered areas of ceiling and covered by at least 3.5" of insulation above the top of the duct insulation jacket may claim effective insulation of R-25 for fiberglass insulation and R-31 for cellulose insulation. ~~The duct system shall identify the segments of the duct which are to be treated as buried and these shall be separately input into the ACM. The ACM shall calculate the correct R-value based on the specified attic insulation R-value, insulation type and duct size. Correct installation of the duct system and attic insulation must be certified by the installer and verified by a HERS rater.~~

Table R4-12 – Buried Duct Effective R-values

	<u>Nominal Round Duct Diameter</u>								
<u>Attic Insulation</u>	<u>4"</u>	<u>5"</u>	<u>6"</u>	<u>7"</u>	<u>8"</u>	<u>10"</u>	<u>12"</u>	<u>14"</u>	<u>16"</u>
-	<u>Effective Duct Insulation R-value for Blown Fiberglass Insulation</u>								
<u>R-30</u>	<u>R-13</u>	<u>R-13</u>	<u>R-13</u>	<u>R-9</u>	<u>R-9</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>
<u>R-38</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-13</u>	<u>R-13</u>	<u>R-9</u>	<u>R-9</u>	<u>R-4.2</u>	<u>R-4.2</u>
<u>R-40</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-13</u>	<u>R-13</u>	<u>R-9</u>	<u>R-9</u>	<u>R-4.2</u>
<u>R-43</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-13</u>	<u>R-9</u>	<u>R-9</u>	<u>R-4.2</u>
<u>R-49</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-13</u>	<u>R-13</u>	<u>R-9</u>
<u>R-60</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-25</u>	<u>R-13</u>
-	<u>Effective Duct Insulation R-value for Blown Cellulose Insulation</u>								
<u>R-30</u>	<u>R-9</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>
<u>R-38</u>	<u>R-15</u>	<u>R-15</u>	<u>R-9</u>	<u>R-9</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>
<u>R-40</u>	<u>R-15</u>	<u>R-15</u>	<u>R-15</u>	<u>R-9</u>	<u>R-9</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>
<u>R-43</u>	<u>R-15</u>	<u>R-15</u>	<u>R-15</u>	<u>R-15</u>	<u>R-9</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>	<u>R-4.2</u>
<u>R-49</u>	<u>R-31</u>	<u>R-31</u>	<u>R-15</u>	<u>R-15</u>	<u>R-15</u>	<u>R-9</u>	<u>R-9</u>	<u>R-4.2</u>	<u>R-4.2</u>
<u>R-60</u>	<u>R-31</u>	<u>R-31</u>	<u>R-31</u>	<u>R-31</u>	<u>R-31</u>	<u>R-15</u>	<u>R-15</u>	<u>R-9</u>	<u>R-9</u>

4.8.6 Fan Flow**Default System Fan Flow**

The default fan flow for an air conditioner and for heating with a heat pump in all climate zones shall be obtained from Table R4-9.

The default heating fan flow for forced air furnaces for all climate zones shall be calculated as follows:

Equation R4-53 $Q_e = 0.50 \times A_{\text{floor}}$

4.8.7 Duct Leakage

Duct leakage factors shown in Table R4-13 shall be used in calculations of delivery effectiveness. Table R4-13 shows default duct leakage factors for dwelling units. Sealed and tested duct systems require the diagnostic leakage test by the installer and verification by a HERS rater meeting the criteria described in ACM RC-2005. The duct leakage factors for sealed and tested new duct systems correspond to sealed duct requirements in newly constructed dwelling units, to entirely new duct systems in existing dwelling units, and to duct systems in alterations and additions that have been sealed to meet the duct leakage requirements of newly constructed buildings. The duct leakage factors for sealed and tested duct systems in existing dwelling units apply only to sealed duct requirements for alterations to existing dwelling units and to extensions of existing duct systems to serve additions. See Section 3.8 for ducts in existing dwelling units that are sealed and tested in conjunction with alterations or additions.

Table R4-13 – Duct Leakage Factors

<u>Case</u>	<u>a_s = a_r =</u>
Untested duct systems in homes built prior to June 1, 2001	<u>0.86</u>
Untested duct systems in homes built after June 1, 2001	<u>0.89</u>
Sealed and tested duct systems in existing dwelling units	<u>0.915</u>
Sealed and tested new duct systems	<u>0.96</u>

4.8.8 Seasonal Distribution System Efficiency

ACMs shall use the following algorithms to calculate duct and HVAC distribution efficiency.

The seasonal distribution system efficiency shall be calculated separately for the heating and cooling seasons using Equation R4-54 based on the seasonal delivery effectiveness from Equation R4-55 and the ~~thermal~~ recovery factor from Equation R4-64. Note that DE_{seasonal}, F_{recov} shall be calculated separately for cooling and heating seasons. Distribution system efficiency shall be determined using the following equation:

$$\text{Equation R4-54} \quad \eta_{\text{dist,seasonal}} = 0.98 \text{ DE}_{\text{seasonal}} \times F_{\text{recov}}$$

where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass. F_{recov} is calculated in Equation R4-64.

4.8.9 Seasonal Delivery Effectiveness

The seasonal delivery effectiveness for heating or cooling systems shall be calculated using Equation R4-55. This value shall be calculated separately for the heating season and the cooling season.

$$\text{Equation R4-55} \quad \text{DE}_{\text{seasonal}} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}$$

where

B_s = Conduction fraction for supply as calculated in Equation R4-56.

B_r = Conduction fraction for return as calculated in Equation R4-57.

ΔT_e = Temperature rise across heat exchanger, °F. This value changes for heating and cooling modes.

ΔT_r = Temperature difference between indoors and the ambient for the return, °F. This value changes for heating and cooling modes.

ΔT_s = Temperature difference between indoors and the ambient for the supply, °F. This value changes for heating and cooling modes.

a_r = Duct leakage factor (1-return leakage) for return ducts. A value is selected from Table R4-13

a_s = Duct leakage factor (1-supply leakage) for supply ducts. A value is selected from Table R4-13

$$\text{Equation R4-56} \quad B_s = \exp \left(\frac{-A_{s,\text{out}}}{1.08 Q_e \times R_s} \right)$$

$$\text{Equation R4-57} \quad B_r = \exp \left(\frac{-A_{r,\text{out}}}{1.08 Q_e \times R_r} \right)$$

where

$A_{s,out}$ = Surface area of supply duct outside conditioned space, ft². See Sections 4.8.1, 4.8.2 and 4.8.3.

$A_{r,out}$ = Surface area of return duct outside conditioned space, ft². See Sections 4.8.1, 4.8.2 and 4.8.3.

Q_e = Flow through air handler fan at operating conditions, cfm. This is determined from Section 4.7.4.

R_r = The effective thermal resistance of return duct, h ft² F/Btu. See Section 4.8.4 and 4.8.5.

R_s = The effective thermal resistance of supply duct, h ft² F/Btu. See Section 4.8.4 and 4.8.5.

4.8.10 RClimate and Duct Ambient Conditions for Ducts Outside Conditioned Space

Duct ambient temperature for both heating and cooling for different duct locations shall be obtained from Table R4-14. Attic temperatures for houses with radiant barriers also shall be obtained from Table R4-14. Reduction of attic temperature and the reduction in solar radiation effect due to radiant barriers shall only be applied to cooling calculations. The eligibility criteria for radiant barriers is given in Section 4.2.1. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F.

Table R4-14 – Assumptions for Duct Ambient Temperature (°F)

Climate zone	Ambient Temperature for Heating, $T_{heat,amb}$			Ambient Temperature for Cooling, $T_{cool,amb}$				
	Attic	Crawl Space	Basement	Attic	Attic w/ radiant barrier (supply)	Attic w/ radiant barrier (return)	Crawl Space	Basement
1	52.0	52.2	48.9	60.0	65.4	61.2	54.0	49.1
2	48.0	48.7	56.5	87.0	84.3	84.2	78.0	64.5
3	55.0	54.9	58.3	80.0	79.4	78.2	71.8	62.8
4	53.0	53.1	56.6	79.0	78.7	77.4	70.9	61.4
5	49.0	49.6	52.3	74.0	75.2	73.1	66.4	56.8
6	57.0	56.7	59.9	81.0	80.1	79.1	72.7	64.1
7	62.0	61.1	60.4	74.0	75.2	73.1	66.4	61.6
8	58.0	57.6	60.1	80.0	79.4	78.2	71.8	63.9
9	53.0	53.1	59.6	87.0	84.3	84.2	78.0	66.4
10	53.0	53.1	61.1	91.0	87.1	87.6	81.6	68.9
11	48.0	48.7	59.5	95.0	89.9	91.0	85.1	69.5
12	50.0	50.4	59.3	91.0	87.1	87.6	81.6	67.8
13	48.0	48.7	58.4	92.0	87.8	88.4	82.4	67.6
14	39.0	40.7	55.4	99.0	92.7	94.4	88.7	68.6
15	50.0	50.4	63.4	102	94.8	96.9	91.3	74.6
16	32.0	34.4	43.9	80.0	79.4	78.2	71.8	54.1

4.8.11 Calculation of Duct Zone Temperatures for Multiple Locations

The temperatures of the duct zones outside the conditioned space are determined in Table R4-14 for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures.

$$\text{Equation R4-58} \quad T_{amb,s} = \frac{(A_{s,attic} + 0.001)T_{attic} + A_{s,crawl} \times T_{crawl} + A_{s,base} \times T_{base}}{A_{s,out}}$$

$$\text{Equation R4-59} \quad T_{\text{amb},r} = \frac{A_{r,\text{attic}} T_{\text{attic}} + A_{r,\text{crawl}} \times T_{\text{crawl}} + A_{r,\text{base}} \times T_{\text{base}}}{A_{r,\text{out}}}$$

The return ambient temperature, $T_{\text{amb},r}$, shall be limited as follows:

- For heating, the maximum $T_{\text{amb},r}$ is $T_{\text{in,heat}}$.
- For cooling, the minimum $T_{\text{amb},r}$ is $T_{\text{in,cool}}$.

4.8.12 Temperature Difference Across Heat Exchanger

The temperature difference across the heat exchanger is determined by Equation R4-60:

For heating:

$$\text{Equation R4-60} \quad \Delta T_e = 55$$

And Equation R4-61 for cooling:

$$\text{Equation R4-61} \quad \Delta T_e = -20$$

4.8.13 Indoor to Duct Location Temperature Differences

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s , and return, ΔT_r , shall be calculated using the indoor and the duct ambient temperatures.

$$\text{Equation R4-62} \quad \Delta T_s = T_{\text{in}} - T_{\text{amb},s}$$

$$\text{Equation R4-63} \quad \Delta T_r = T_{\text{in}} - T_{\text{amb},r}$$

4.8.14 Thermal Regain (F_{regain})

The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The thermal regain factors that are required to be used are provided in

Table R4-15.

Supply Duct Location	Thermal Regain Factor [Fregain]
Attic	0.10
Crawl Space	0.12
Basement	0.30
Other	0.10

Table R4-15 – Thermal Regain Factors

Supply Duct Location	Thermal Regain Factor [F_{regain}]
Attic	0.10
Crawl Space	0.12
Basement	0.30
Other	0.10

4.8.15 Recovery Factor (F_{recov})

The recovery factor, F_{recov} , shall be calculated based on the thermal regain factor, F_{regain} , and the duct losses without return leakage.

$$\text{Equation R4-64} \quad F_{\text{recov}} = 1 + F_{\text{regain}} \left(\frac{1 - a_s B_s + a_s B_s (1 - B_r) \frac{\Delta T_r}{\Delta T_e} + a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}}{DE_{\text{seasonal}}} \right)$$

4.9 Hourly Attic Duct Efficiency Multipliers

The algorithm in this section shall be used to model the hourly variation in duct efficiency for ducts located in attics. No hourly variation is modeled for ducts located in spaces other than attics. The multipliers are determined as described in Section 4.9.1 below:

4.9.1 Hourly Duct Efficiency Multipliers

The hourly duct efficiency multiplier for ducts in attics shall be calculated for each hour using Equation R4-65 through Equation R4-68.

$$\text{Equation R4-65} \quad DEM_{\text{hr}} = 1 + C_{\text{DT}} \times \left(\frac{\Delta T_{\text{sol,hr}}}{\Delta T_{\text{sol,season}}} - 1 \right)$$

$$\text{Equation R4-66} \quad \Delta T_{\text{sol,hr}} = T_{\text{solair,hr}} - T_{\text{in,hr}}$$

$$\text{Equation R4-67} \quad T_{\text{solair,hr}} = T_{\text{amb,hr}} + \left(\frac{\alpha}{h_o} \right) \times I_{\text{hor,hr}} - \Delta T_{\text{sky}}$$

$$\text{Equation R4-68} \quad C_{\text{DT}} = C_0 + \frac{C_R}{R_{\text{duct}}} + C_L L_{\text{duct}}$$

where

DEM_{hr} = The hourly duct efficiency multiplier for ducts located in all locations. This value is calculated for each hour and separately for the heating season ($HDEM_{\text{hr}}$) and cooling season ($CDEM_{\text{hr}}$).

$T_{sol,air,hr}$	Sol-air temperature, °F. See Equation R4-67.
$T_{in,hr}$	Indoor air dry-bulb temperature from simulation, °F.
$T_{amb,hr}$	Outdoor air dry-bulb temperature, °F. From the CEC weather file.
ΔT_{sky}	Reduction of sol-air temperature due to sky radiation, = 6.5 °F.
$I_{hor,hr}$	Global solar radiation on horizontal surface, Btu/h-ft ² . From the CEC weather file.
α	Solar absorptivity of roof = 0.50.
h_o	Outside surface convection coefficient, = 3.42 Btu/h-ft ² -°F.
$\Delta T_{sol, season}$	Energy weighted seasonal average difference between sol-air and indoor temperatures. This is taken from Table R4-17.
R_{duct}	Duct insulation R-value, hr ft ² -°F/Btu.
L_{duct}	Duct leakage as fraction of supply airflow, dimensionless. See Table R4-13.
C_{DT}, C_0, C_R, C_L	Regression coefficients. See Table R4-16.

Table R4-16 – Regression Coefficients

	Cooling		Heating	
	Radiant Barrier	No Radiant Barrier	Radiant Barrier	No Radiant Barrier
C_0 (Unitless)	0.0078	0.0186	0.0350	0.0205
C_R (h-ft ² -°F/Btu)	0.1222	0.0877	0.0794	0.1202
C_L (Unitless)	0.5480	0.2995	0.0714	0.2655

Table R4-17 – Seasonal Sol-Air Temperature Difference, °F

Climate Zone	Cooling	Heating
1	23.00	-20.01
2	31.69	-23.64
3	23.66	-18.90
4	26.29	-21.13
5	26.02	-20.25
6	23.79	-17.12
7	25.17	-17.16
8	30.89	-19.46
9	32.73	-18.85
10	33.34	-21.53
11	34.24	-24.38
12	34.65	-23.31
13	34.53	-22.92
14	35.29	-25.64
15	33.33	-20.32
16	29.43	-29.86

4.94.10 Water Heating Calculations Method

The water heating budget is the TDV energy that would be used by a system that meets the requirements of the standards (see Section 3.7 for details). The calculation procedure is documented in ACM RG-2005.

This section describes the calculation methods to use with residential water heating systems. The equations listed here must be implemented exactly in general purpose ACMS.

•Water Heating Energy Use

The total water heating energy use is the water heating energy use summed over all water heating systems, all water heaters, and all dwelling units being modeled.

$$WHEU_{tot} = \sum_{k=1}^M (WHEU_k \times NmbrWHtr_k) \quad \text{Equation 4.30}$$

For the *Proposed Design*, Equation 4.31 applies:

$$WHEU_{proposed} = WHEU_{tot} \times \frac{1000}{CFA_{tot}} \quad \text{Equation 4.31}$$

$$CFA_{tot} = \sum_{i=1}^N CFA_i \quad \text{Equation 4.32}$$

Where:

- $WHEU_{tot}$ — total water heating energy use
- $WHEU_k$ — water heating energy use for the k^{th} water heating system
- $NmbrWHtr_k$ — number of water heaters in k^{th} water heating system
- CFA_i — conditioned floor area of the i^{th} dwelling unit (ft^2). The CFA is limited to a maximum of 2,500 ft^2
- N — Number of dwelling units.

•Water Heating Energy Budget

The water heating energy budget (WHEB) for a water heating system or a building is determined from the following equation. The budget may be calculated for a system that serves a set of dwelling units or for the entire building. The budget for individual units in a multi-family applications may be expressed as a total, as shown in Equation 4.33.

$$WHEB = 0.00485 \times \sum_{i=1}^N CFA_i + 16.37N \quad \text{Equation 4.33}$$

Where CFA_i and N are as described in Section 4.21.1

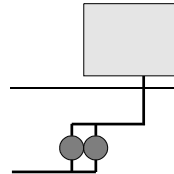
•Water Heating Systems

Water heating distribution systems may serve more than one dwelling unit and may have more than one piece of water heating equipment. The energy used by a water heating system is calculated as the sum of the energy used by each individual water heater in the system. Energy used for the whole building is calculated as the sum of the energy used by each of the water heating systems. To delineate different water heating elements several indices are used.

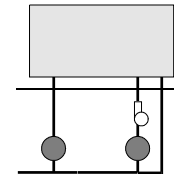
- i — Used to describe an individual dwelling unit. For instance CFA_i would be the conditioned floor area of the i th dwelling unit. "N" is the total number of dwelling units.
- j — Used to refer to the number of water heaters in a system. "M" is the total number of water heaters.
- k — Used to refer to a water heating system or distribution system. A building can have more than one system and each system can have more than one water heater.

The following diagrams illustrate some of the cases that are recognized by the Commission water heating method.

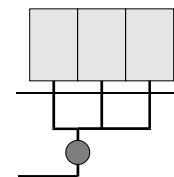
- 1 One distribution system with two water heaters serving a single dwelling unit.



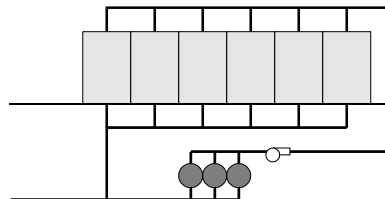
- 2 Two distribution systems, each with a single water heater serving a single dwelling unit.



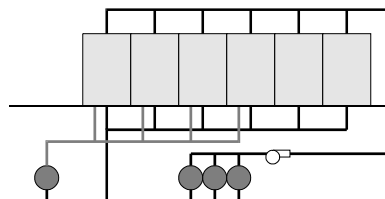
- 3 One distribution system with one water heater serving multiple dwelling units.



- 4 Single distribution system with multiple water heaters serving multiple units.



- 5 Two distribution systems, one with multiple water heaters serving multiple dwelling units. The recirculating distribution system serves all the units. The other serves only four units.



The following rules apply to the calculation of water heating system energy use:

B.1 water heater type per system

C.1 solar or woodstove credit (but not both) per system

*Adjusted Recovery Load (ARL)

The adjusted recovery load is calculated separately for each water heating distribution system, k . It accounts for the number of units served, the size of each unit and the type of distribution system. ARL_k is given by the following equations for the k th distribution system.

$$ARL_k = SRL_k DSM_k SSM_k \quad \text{Equation 4.34}$$

Where

SRL_k = Standard water heating recovery load of the kth water heating distribution system (million Btu/yr).

DSM_k = Distribution system multiplier (unitless) for the kth water heating system. A value of one is used for standard distribution systems. (See Table 4-8)

SSM_k = Solar savings multiplier (unitless) for the kth water heating system. See equation below.

$$SSM_k = 1 - (SSF_k A) \quad \text{Equation 4.35}$$

SSF_k = Solar savings fraction taken from an f-Chart analysis or other approved method (unitless).

A = Adjustment to the SSF (unitless). This value is 0.80 to account for pumping energy and piping heat loss effects when these losses are not accounted for in the f-Chart analysis and 1.00 for passive systems (no circulation pump) and systems where pump energy and piping losses were included in the f-Chart analysis. (Piping loss effects are accounted for in the Commission Passive Solar Credit calculation procedure). Approved ACM compliance supplements shall state that pipe losses are not to be accounted for in the f-Chart analysis of active solar water heating systems.

When a water heating system has more than one water heater, the total load on the system is assumed to be shared equally by each water heater. The ARL for the jth water heater is then shown in the following equation.

$$ARL_j = \frac{ARL_k}{N_{mbrEquip_k}} \quad \text{Equation 4.36}$$

Where

$N_{mbrEquip_k}$ = The number of water heaters in the kth system.

•Standard Recovery Load

The standard water heating recovery load for the kth system is the load assuming a standard distribution system and no solar or wood stove credits. It depends on the size of the dwellings and number of units and is given in the following equation (million Btu/yr).

$$SRL_k = \sum_{i=1}^n \frac{0.0855347 \left(\frac{CFA_i}{1000} \right)^2 + 3.61307 \left(\frac{CFA_i}{1000} \right) + 6.036}{N_{mbrSys_i}} \quad \text{Equation 4.37}$$

Where

CFA_i = Conditioned floor area of the ith dwelling unit served by the water heater (ft^2). The CFA is limited to a maximum of 2,500 ft^2 per dwelling unit.

n = Number of dwelling units served by the kth water heating system.

N_{mbrSys_i} = Number of water heating systems that serve the ith dwelling unit. When a dwelling unit is served by more than one system, the assumption is that the load is shared equally by each system.

•Distribution System Multiplier

The distribution system multiplier (unitless) is an adjustment for alternative water heating distribution systems. A value of one is used for standard distribution systems. Values for other systems are given in the following table

Table R 4-10 – Distribution System Multipliers (DSMs)

Distribution System		DSM – Single Family	DSM MultiFamily
Standard		1.00	1.00
POU		0.82	na
HWR		0.82	na
Pipe Insulation		0.92	0.92
Parallel Piping		0.86	0.86
Recirc/NoControl		1.52	1.52
Recirc/Timer		1.28	na
Recirc/Temp		1.05	1.05
Recirc/Demand		0.98	na
Recirc/Time+Temp		0.96	na
Recirc/Demand + HWR		0.80	na
Recirc/Demand + Pipe Insulation		0.90	na

•Energy Use of Individual Water Heaters

Once the adjusted recovery load is determined for each water heater, the energy use for each water heater is calculated as described below for each water heater type.

•Storage Gas, Storage Electric and Heat Pump Water Heaters

The energy use of storage gas, storage electric and heat pump water heaters is given by the following equation.

$$WHEU_j = \left[\frac{ARL_j \times HPAF_j}{LDEF_j} \right] WSAF_j \quad \text{Equation 4.38}$$

Where

$WHEU_j$ = Energy use of the water heater (millions Btu/yr), adjusted for tank insulation and wood stove boilers.

ARL_j = Adjusted recovery load (millions Btu/yr). Equations for this value are given in Section 4.21.4.

SEM_j = Source energy multiplier (unitless). This multiplier is 3.0 for electric and heat pump water heaters and 1.0 for gas or oil water heaters.

$HPAF_j$ = Heat pump adjustment factor from the table below based on climate zone. This value is one for storage gas, storage oil and storage electric water heaters.

Table R4-11 – Heat Pump Adjustment Factors

Climate Zone	Heat Pump Adjustment Factor	Climate Zone	Heat Pump Adjustment Factor
--------------	-----------------------------	--------------	-----------------------------

1	1.040	9	0.920
2	0.990	10	0.920
3	0.990	11	0.920
4	1.070	12	1.070
5	1.070	13	0.920
6	0.920	14	1.040
7	0.920	15	0.920
8	0.920	16	1.500

~~LDEF_j = The load dependent energy factor (LDEF) is given by the following equation. This equation adjusts the standard EF for different load conditions.~~

$$\text{LDEF}_j = \ln\left(\frac{ARL_j \times 1000}{365}\right) \left(a \times EF_j + b \right) + \left(c \times EF_j + d \right) \quad \text{Equation 4.39}$$

~~a,b,c,d = Coefficients from the table below based on the water heater type.~~

Table R4-12 – LDEF Coefficients

Coefficient	Storage Gas	Storage Electric	Heat Pump
A	0.098311	0.91263	0.44189
B	0.240182	0.94278	0.28361
C	1.356491	4.31687	0.71673
D	0.872446	3.42732	1.13480

~~EF_j = Energy factor of the water heater (unitless). This is based on the DOE test procedure.~~

~~WSAF_k = Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.~~

•Instantaneous Gas or Oil

~~The energy use for instantaneous gas or oil water heaters is given by the following equation.~~

$$\text{WHEU}_j = \left[\frac{ARL_j \times SEM_j}{EF_j} + \frac{PILOT_j \times 8760}{1000000} \right] WSAF_j \quad \text{Equation 4.40}$$

Where

~~ARL_j = Adjusted recovery load from Section 4.21.4.~~

~~SEM_j = Source energy multiplier (unitless). This multiplier is 1.0 for gas or oil water heaters and can therefore be ignored.~~

~~EF_j = Energy factor from the DOE test procedure (unitless). This is taken from manufacturers literature or from the CEC Appliance Database.~~

~~PILOT_j = Energy consumption of the pilot light (Btu/h).~~

$WSAF_k =$ Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

•Instantaneous Electric

Energy use for instantaneous electric water heaters is given by the following equation.

$$WHEU_j = \left[\frac{ARL_j \times SEM_j}{EF_j} \right] WSAF_j \quad \text{Equation 4.41}$$

$ARL_j =$ Adjusted recovery load from Section 4.21.4.

$SEM_j =$ Source energy multiplier (unitless). This multiplier is 3.0 for electric water heaters.

$EF_j =$ Energy factor from DOE test procedure (unitless).

$WSAF_k =$ Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

•Large storage gas and Indirect Gas

Energy use for large storage gas and indirect gas water heaters is given by the following equation. Note: large storage gas water heaters are defined as any gas storage water heater with an input rate not less than 75,000 Btu/h.

$$WHEU_j = \left[\frac{ARL_j + (JL_j)}{EFF_j \times EAF_j} + PILOT_j \left(\frac{8760}{1000000} \right) \right] WSAF_j \quad \text{Equation 4.42}$$

[SBL_j has been deleted from this equation]

Where

$ARL_j =$ Adjusted recovery load (defined later).

$JL_j =$ Jacket loss (millions Btu/yr). Equations are given in Section 4.21.7.

$EFF_j =$ Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

$EAF_j =$ Efficiency adjustment factor (unitless). This value is 1.0 for large storage gas water heaters and 0.98 for indirect gas water heaters.

$PILOT_j =$ Pilot light energy (Btu/h).

$WSAF_k =$ Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

•Wood Stove Adjustment Factors

This is an optional capability and the Wood Stove Boiler Adjustment Factor is set to 1.00 for ACMs without wood stove boiler modeling capability. The wood stove adjustment factor (unitless) reduces water heating energy to account for the heat contribution of wood stove boilers. This multiplier is taken from the table below, based on climate zone and whether or not the wood stove boiler has a recirculation pump. The inclusion of

this factor and its relevant input parameters is an optional capability for ACMs. However, when this optional capability is implemented the algorithms and procedures given below must be used.

Table R4-13 – Wood Stove Adjustment Factors

Climate Zone	Wood Stoves with Pumps	Wood Stoves without Pumps
1	0.775	0.750
2	0.775	0.750
3	0.775	0.750
4	0.865	0.850
5	0.865	0.850
6	0.910	0.900
7	0.910	0.900
8	0.955	0.950
9	0.910	0.900
10	0.955	0.950
11	0.910	0.900
12	0.865	0.850
13	0.910	0.900
14	0.910	0.900
15	1.000	1.000
16	0.730	0.700

•Tank Surface Area

Tank surface area (TSA) is used to calculate the jacket loss (JL) for large storage gas and indirect gas water heaters. TSA is given in the following equation as a function of the tank volume.

$$TSA_j = e (f VOL_j^{0.33} + g)^2 \quad \text{Equation 4.43}$$

Where

VOL_j = Actual tank capacity (gallons).

e,f,g = Coefficients given in the following table.

Table R4-14 – Coefficients for Calculating Tank Surface Areas

Coefficient	Storage Gas	Large Storage Gas and Indirect Gas	Storage Electric and Heat Pumps
e	0.00793	0.01130	0.01010

f	15.67	11.8	11.8
g	1.9	5.0	5.0

~~*Jacket Loss~~

The jacket loss for large storage gas and indirect gas water heaters

$$JL_j = \left(\frac{TSA_j(135 - 60.3)}{RTI_j + REI_j} + (FTL_j)(EFF_j)(EAF_j) \right) \left(\frac{8760}{1000000} \right) \quad \text{Equation 4.44}$$

Where

TSA_j = Tank surface area (ft²).

FTL_j = Fitting losses. This is a constant 61.4 Btu/h.

REI_j = R-value of exterior insulating wrap.

$$RTI_j = \left(\frac{TSA_j(135 - 60.3)}{(8.345(VOL_j)(SBL_j)(135 - 60.3) - FTL_j - PILOT_j)(EFF_j)(EAF_j)} \right) \quad \text{Equation 4.45}$$

SBL_j = Standby loss expressed as a fraction of the heat content of the stored water lost per hour from the GEC Appliance Database or from manufacturer's literature.

Where EFF_j and EAF_j are efficiencies as described in Section 4.21.5.4